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CROP IDENTIFICATION TECHNOLOGY ASSESSMENT
FOR REMOTE SENSING (CITARS)

VOLUME I
TASK DESIGN PLAN



National Aeronautics and Space Administration
LYNDON B. JOHNSON SPACE CENTER

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| 13. ABSTRACT <p>This document sets out the design plan for a joint task to quantify the crop identification performances resulting from the remote identification of corn, soybeans, and wheat. Automatic data processing techniques developed by the Earth Observations Division of the Lyndon B. Johnson Space Center of NASA, the Environmental Research Institute of Michigan, and the Laboratory for Applications of Remote Sensing of Purdue University will be used in the quantification. The Agricultural Stabilization and Conservation Service of the U.S. Department of Agriculture will assist these three institutions in performing the task by furnishing ground-truth data.</p> <p>Steps for the conversion of multispectral data tapes to classification results will be specified. The crop identification performances resulting from the use of several basic types of automatic data processing techniques will be compared and examined for significant differences. The techniques will be evaluated also for changes in geographic location, time of the year, management practices, and other physical factors.</p> <p>The results of the Crop Identification Technology Assessment for Remote Sensing task will be applied extensively in the Large Area Crop Inventory Experiment.</p> | | | | | | | | | | | | | | | | |
| 14. SUBJECT TERMS | | | | | | | | | | | | | | | | |
| <table border="0"> <tr> <td>Classification</td> <td></td> <td></td> </tr> <tr> <td><u>algorithm</u></td> <td><u>Multitemporal data</u></td> <td><u>Statistical evaluation</u></td> </tr> <tr> <td><u>Crop identification</u></td> <td><u>Quantification</u></td> <td></td> </tr> <tr> <td><u>performance</u></td> <td><u>Radiometric</u></td> <td></td> </tr> <tr> <td><u>Multispectral data</u></td> <td><u>preprocessing</u></td> <td></td> </tr> </table> | | Classification | | | <u>algorithm</u> | <u>Multitemporal data</u> | <u>Statistical evaluation</u> | <u>Crop identification</u> | <u>Quantification</u> | | <u>performance</u> | <u>Radiometric</u> | | <u>Multispectral data</u> | <u>preprocessing</u> | |
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| <u>performance</u> | <u>Radiometric</u> | | | | | | | | | | | | | | | |
| <u>Multispectral data</u> | <u>preprocessing</u> | | | | | | | | | | | | | | | |

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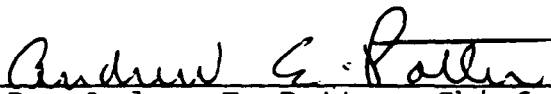
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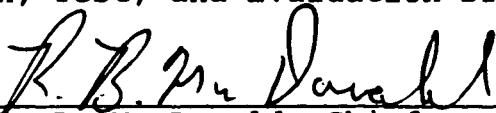


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PREFACE

Because of the synoptic data acquisition capabilities of satellites and high-altitude aircraft and the speed and accuracy with which such data can be automatically processed, there is a growing conviction that existing remote sensing technology can be used to make crop inventories of much larger areas than the relatively local areas for which this technology was developed. The Crop Identification Technology Assessment for Remote Sensing is being designed to evaluate this capability. It will be an integral phase of the Large Area Crop Inventory Experiment.

Participants in the task are the National Aeronautics and Space Administration/Lyndon B. Johnson Space Center/Earth Observations Division, the Environmental Research Institute of Michigan, the Laboratory for Applications of Remote Sensing of Purdue University, and the Goddard Space Flight Center. The Agricultural Stabilization Conservation Service of the U.S. Department of Agriculture has agreed to support the task by collecting the ground-truth data required to test the accuracy of the remote sensing procedures. Personnel at the University of Houston, the University of Texas at Dallas, and Rice University also contributed to the preliminary planning.

The planned documentation for the activity of the Crop Identification Technology Assessment for Remote Sensing is:

Volume I, Task Design Plan

Volume II, Ground Truth Data

Volume III, Data Acquisition

Volume IV, Image Analysis

Volume V, Data Preparation

Volume VI, Data Processing by the Laboratory for Applications of Remote Sensing

Volume VII, Data Processing by the Environmental Research Institute of Michigan

Volume VIII, Data Processing by the National Aeronautics and Space Administration/Lyndon B. Johnson Space Center/Earth Observations Division

Volume IX, Analysis of Results

Volume X, Final Report

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Dr. Emil Jebe and Mr. William A. Malila, Environmental Research Institute of Michigan

GLOSSARY

- ACORN4 — an algorithm used by the Environmental Research Institute of Michigan for correcting data for scan-angle-dependent variations before classification
- ADP — automatic data processing
- ASCS — Agricultural Stabilization and Conservation Service of the U.S. Department of Agriculture
- BSI — Batch System Interface, a classification subsystem of the Earth Resources Interactive Processing System
- CCP — crop classification performance, level of crop performance to be determined by analysis-of-variance testing
- CCT — computer-compatible tape containing digital satellite data
- CIP — crop identification performance, the quantitative assessment of crop inventories in specified areas using remote sensing, photointerpretation, and ADP techniques
- CITARS — Crop Identification Technology Assessment for Remote Sensing
- Clustering — a mathematical procedure for organizing multi-spectral data into spectrally homogeneous groups

x

CRT — cathode-ray tube

CY — calendar year

DAS — data analysis station, a computer system for reformatting, analyzing, and reviewing digital, remotely sensed data

DS&AD — Data Systems and Analysis Directorate of the Lyndon B. Johnson Space Center, NASA

EOD — Earth Observations Division of the Lyndon B. Johnson Space Center, NASA

EREP — Earth Resources Experiment Package, consisting of remote sensors mounted on the Skylab spacecraft

ERIM — Environmental Research Institute of Michigan

ERIPS — Earth Resources Interactive Processing System, a system at the Lyndon B. Johnson Space Center, NASA, which provides real-time interaction of an investigator with several digital, spectral analysis procedures

ERPO — Earth Resources Program Office at the Lyndon B. Johnson Space Center, NASA

ERTS-1 — the first Earth Resources Technology Satellite, which was launched in June 1972, orbits the Earth 14 times a day from an altitude of 915 kilometers, and scans the same scene every 18 days

ERTS-B — the second Earth Resources Technology Satellite, which will be launched in January 1975.

FOD — Flight Operations Directorate of the Lyndon B. Johnson Space Center, NASA

FY — fiscal year

GDSD — Ground Data Systems Division of the Lyndon B. Johnson Space Center, NASA

Gray map — a CRT digital image composed of a scale of gray tones.

Ground truth — data collected by ground observations of the ASCS on selected sections for the CITARS task

GSFC — Goddard Space Flight Center, NASA, located in Greenbelt, Maryland

ISOCLS — Iterative Self-Organizing Clustering System, a computer program developed by the EOD which uses a clustering algorithm to group homogeneous spectral data

JSC — Lyndon B. Johnson Space Center of NASA

LACIE — Large Area Crop Inventory Experiment, which will utilize the results of the CITARS task in future crop inventories

LACIP -- Large Area Crop Inventory Project which was renamed
LACIE

LARS -- Laboratory for Applications of Remote Sensing
of Purdue University

LARSYS -- a system of classification programs developed at
the LARS

Local recognition -- a condition for establishing CIP where
crop signatures for classifier training are obtained
from the geographic region in which the crops are
identified

LOE -- level of effort, used to designate an undetermined
work force on a project when equivalent man-hours
cannot be accurately estimated

M²S -- aircraft, modular, multiband 11-channel scanner
developed by The Bendix Corporation

M-7 -- aircraft, modular, 12-channel scanner developed by
the ERIM

MIST -- multispectral image tape, to which data are transferred
and stored at LARS

MSDS -- Multispectral Data System at JSC, which includes an
aircraft 24-channel scanner and a ground DAS

MSP — multitemporal processing

MSS — multispectral scanner onboard the ERTS-1

NASA — National Aeronautics and Space Administration

Nonlocal recognition — a condition for establishing CIP where crop signatures for classifier training are obtained from a geographic region other than the one in which the crops are identified

'NSA' — an ERIM computer descriptor used to specify the input format for field boundary coordinates

PCM — pulse-code modulated

Pixel — a picture element which refers to one instantaneous field of view as recorded by the ERTS-1 MSS and covers the equivalent of 0.44 hectare (1.09 acres) (One ERTS-1 frame contains approximately 7.36×10^6 pixels.)

PSP — preprocessing and standard processing

PTD — Photographic Technology Division of JSC

Quarter section — one quarter of a section of land selected for ASCS field visits

RTOP — Research and Technology Operational Plan

Sl90A - multispectral photographic system on the Skylab spacecraft

Sl90B - Earth terrain photographic system on the Skylab spacecraft

S&AD - Science and Applications Directorate of JSC

Section - a 1.6- by 8-kilometer subdivision of the test segment, selected for extraction of test data

SRS - Statistical Reporting Service of the U.S. Department of Agriculture

SRT - Supporting Research and Technology, a team effort of EOD, ERIM, and LARS

Test segment - an 8- by 32-kilometer (25,856-hectare or 64,600-acre) parcel of land selected for extracting MSS data

UP - unresolved objects processing

USDA - U.S. Department of Agriculture

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1.0 INTRODUCTION

1.1 TASK DESCRIPTION

The objective of the Crop Identification Technology Assessment for Remote Sensing (CITARS) will be the quantification of the crop identification performances (CIP's) resulting from the remote identification of corn, soybeans, and wheat, using automatic data processing (ADP) techniques. The ADP techniques will be automatic in the sense that subjective human interactions with the classification algorithms will be minimized by specifying the steps required for an analyst to convert a multispectral data tape to a classification result. The capability demonstration will require:

1. The definition of specifications for well-defined ADP techniques for making crop area inventories and quantitatively assessing the CIP of each area
2. The definition of feasible aircraft and spacecraft sensor platforms
3. The definition of a sampling strategy optimally designed for the demonstration project, the ADP procedure chosen, and the platform used
4. The definition of a specific procedure for converting the remotely sensed crop identification data to crop area estimates in the demonstration region

The results of the CITARS task will be applied extensively in the Large Area Crop Inventory Experiment (LACIE).

1.2 BACKGROUND

1.2.1 Remote Sensing Data Processing Procedures

In May 1968, the Earth Resources Group was formed to plan and direct remote sensing activities at the National Aeronautics and Space Administration (NASA) Lyndon B. Johnson Space Center (JSC). This group became the Earth Observations Division (EOD) under the Science and Applications Directorate (S&AD) of NASA/JSC in February of 1970. The EOD has directed and participated in a team effort called Supporting Research and Technology (SRT). An SRT team of which EOD is a member is composed also of the Environmental Research Institute of Michigan (ERIM) and the Laboratory for Applications of Remote Sensing of Purdue University (LARS). The research and development of techniques for converting remotely acquired spectral data to usable resource information has been a major project of this SRT team. At the same time, EOD has participated with various user agencies in defining the importance of certain applications resource information to these agencies, their requirements, and the capability of the technology base developed by the SRT team to satisfy these requirements.

The primary products of the SRT techniques/applications research and development activity are:

1. Remote sensing, photointerpretive, and ADP techniques for the extraction of resource information from multi-spectral imagery
2. A defined set of applications resource information requirements, with defined priorities

3. Knowledge, through testing and evaluating the techniques and their applicability to the applications resource requirements, of the feasibility of using existing techniques to satisfy these requirements
4. A rational basis for decisions to discontinue or pursue the further development of techniques for particular applications requirements

The ADP products have already been used to process some data from the first Earth Resources Technology Satellite (ERTS-1) and from high-altitude aircraft. The accuracy of the crop identifications has convinced EOD and others in the remote sensing community that the capability exists for making crop inventories over large areas.

1.2.2 Large-Area Inventory Procedure

A procedure for making large-area inventories is well established and has been successfully used by the Statistical Reporting Service (SRS) of the U.S. Department of Agriculture (USDA) in its crop production estimate program. The estimate procedure consists of three steps:

1. Strategic selection of areas to be intensively examined for crop content
2. Identification of crops contained in the sampling areas
3. Measurement of the amount of each crop type within the selected areas

Errors arising as a result of this procedure are the incorrect identification of crops, the inaccurate mensuration or area measurement, and the sample error.

A similar procedure can be envisioned for a remote sensing system, with the same error sources. The synoptic acquisition capabilities of satellites and possibly high-altitude aircraft can result in adequate coverage to reduce significantly the occurrence of sample errors using conventional techniques. Because crop identification errors arising from the processing of multispectral scanner (MSS) data could lead to significant inaccuracies in crop inventories, a careful evaluation is necessary before a large area crop inventory is designed using existing remote sensing technology.

2.0 APPROACH

The remote sensing data will be collected by MSS onboard satellites and high-altitude aircraft. The recently developed ADP procedures will then be used to classify the data obtained within the six test areas of the U.S. Corn Belt. The periodic acquisition of data will continue throughout most of the growing seasons for corn, soybeans, and wheat.

Ground truth for these areas will be acquired concomitantly with the spacecraft and aircraft data by a combination of field visits and the interpretation of large-scale aircraft photographs. These data will identify crops and other important agricultural conditions.

Classification results from the MSS data and ADP techniques will be compared to the ground-truth data to establish the CIP's. These CIP's will be determined for several periods during the growing season for both of the conditions anticipated for an operational system:

1. Local recognition: Crop signatures for classifier training will be obtained from the geographic region in which the crops are identified.
2. Nonlocal recognition: Crop signatures for classifier training will be obtained from a geographic region other than the region in which the crops are identified.

Differences will be observed in the crop identification capabilities of each ADP technique when aircraft and spacecraft data are processed. These will be analyzed and examined for the situations described in conditions 1 and 2.

Upon establishment of the CIP for each type of data processing technique in the two basic remote sensing situations described, differences in the performances of these types of processing techniques for crop identification will be established. The signature extension capability also will be ascertained for each ADP technique by determining whether CIP's for local recognition differ significantly from CIP's for nonlocal recognition. Finally, the performances of the ADP techniques in each of the remote sensing situations discussed will be compared and examined for significant differences.

To specify the well-defined ADP techniques for the capability demonstration, the CIP's of these techniques, and the agricultural and meteorological conditions associated with these performances, the following questions will have to be answered:

1. How do corn, soybean, and wheat identifications vary with time during the growing season?
2. How do CIP's vary among different geographic locations having different soils, weather, management practices, crop distributions, and field sizes?
3. Can statistics acquired from one time or location be used to identify crops at other times and/or locations?
4. How much variation in CIP is observed when different data analysis techniques are used?
5. Does the use of multitemporal data increase CIP?
6. Does the use of radiometric preprocessing extend the use of training statistics and/or increase CIP?

7. How much deviation in CIP occurs when the selection of training sets varies?
8. Are similar CIP results obtainable from spacecraft and aircraft data acquisition systems?

After the CIP for each of these questions is estimated, analysts will determine whether any observed differences are significant.

3.0 DETERMINATION OF TEST AREAS

3.1 TEST SITES

The CITARS test sites have been selected by the Agricultural Stabilization and Conservation Service (ASCS) of the USDA, ERIM, EOD, and LARS to satisfy the following requirements:

1. To include the range of climatic and agricultural conditions characteristic of the U.S. Corn Belt
2. To maximize the probability of obtaining repeated, cloud-free coverage by the spacecraft MSS
3. To minimize the statistical bias attributable to the process of site selection
4. To conserve the aircraft resources required to obtain MSS data and aerial photographs

Repeated coverage by the ERTS-1 MSS was assured by limiting site selection to the four overlap zones of the five ERTS-1 passes over Indiana and Illinois (passes L, M, N, O, and P). The agricultural records of these states were used to stratify the counties within each zone with respect to such factors as climate, distribution of crops, crop productivity, soil type, variability of soil color, and topography. The following results were obtained.

| <u>ERTS pass</u> | <u>State</u> | <u>County</u> |
|----------------------|--------------|---|
| L/M | Indiana | Grant, Huntington |
| L/M | Indiana | Madison, Hancock, Shelby |
| M/N | Indiana | White, Tippecanoe, Benton |
| N/O | Illinois | Fayette, Marion, Washington, Perry |
| N/O | Illinois | Piatt, Grundy, Macon, McLean, Livingston, Ford |
| O/P | Illinois | Ogle, Lee, Bureau, Whiteside |

Based on the location of available ASCS ground data collection resources, one county was then selected from each group. The counties selected were Huntington, Shelby, and White Counties in Indiana and Livingston, Fayette, and Lee Counties in Illinois (fig. 1).

3.2 TEST SEGMENTS

The average positions of ERTS-1 ground tracks L through P for the period of December 1972 through February 1973 were plotted on 1:250,000-scale topographic maps (fig. 2) to determine the probable limits of overlapping MSS coverage within the selected counties. A test segment was selected at random from within the defined area for each county to double the opportunity for acquiring MSS data for a segment. The test segments are 8 by 32 kilometers to provide an area small enough for field visits but large enough to provide a representative sample of agriculture within the county. The 32-kilometer-long axis is on a north-south line.

3.3 SECTIONS

3.3.1 Quarter Sections

Each 8- by 32-kilometer segment was divided into five columns and four rows of 1.6- by 8-kilometer sections. One quarter-section tract was selected at random within each of the 20 sections. The small-scale imagery (scale: 1 inch = 1.6 kilometers) of each quarter section was examined. If water, trees, urban development, air, fields, or other readily identifiable, nonagricultural-use features occupied more than 10 percent of the quarter section (20 percent in Huntington County where small wooded areas are common), a replacement tract was selected. The quarter sections will be used for field visits by the ASCS to obtain ground-truth data. The procedures for selecting sections and quarter sections are set out in greater detail in appendix A.

3.3.2 Test Sections

One additional section, disjointed from each quarter section, was then randomly chosen from each of the 20 sections. The ground-cover classes in these sections will be identified by photointerpretation and will serve as test sections for the evaluation of CIP. Appendix D shows the distribution of quarter-section and test-section tracts selected for ground investigation in each county.

3.4 FIELDS

Data for the CITARS experiment have been collected from training fields, test fields, and pilot fields.

(See appendix B for training, pilot, and test field selection procedures.)

3.4.1 Training Fields

Ten quarter sections will be selected at random from the 20 ASCS quarter sections in each segment. From the 10 quarter sections selected, all crop fields large enough to be accurately located in the scanner imagery will be available for training the classifier.

Training areas for nonagricultural types not present in the 10 quarter sections, such as water bodies, forests, towns, and airports, will be selected arbitrarily from the base photography. If present in the segment, 10 areas of nonagricultural type will be selected, and their coordinates will be located in the scanner imagery.

In order to compare results, all classifications will be performed using these training fields. No additional fields may be selected for training during the analysis.

3.4.2 Pilot and Test Fields

All the fields in the 20 photointerpreted sections will be designated as test fields unless an estimate of classification errors is required. Then all the fields in one-half of the 20 photointerpreted sections will be designated as pilot fields, and the remaining fields will serve as test fields. The pilot fields will be used to determine the feasibility of correcting for the bias in the classified crop proportions resulting from classification errors.

Errors will be estimated in these fields, and the correction determined from these estimates will be applied to the test field classification results. (Appendix C gives the procedures for locating test field boundaries.)

Data gathered from the test fields will be classified by ADP techniques and used, along with other specified data, to determine CIP's.

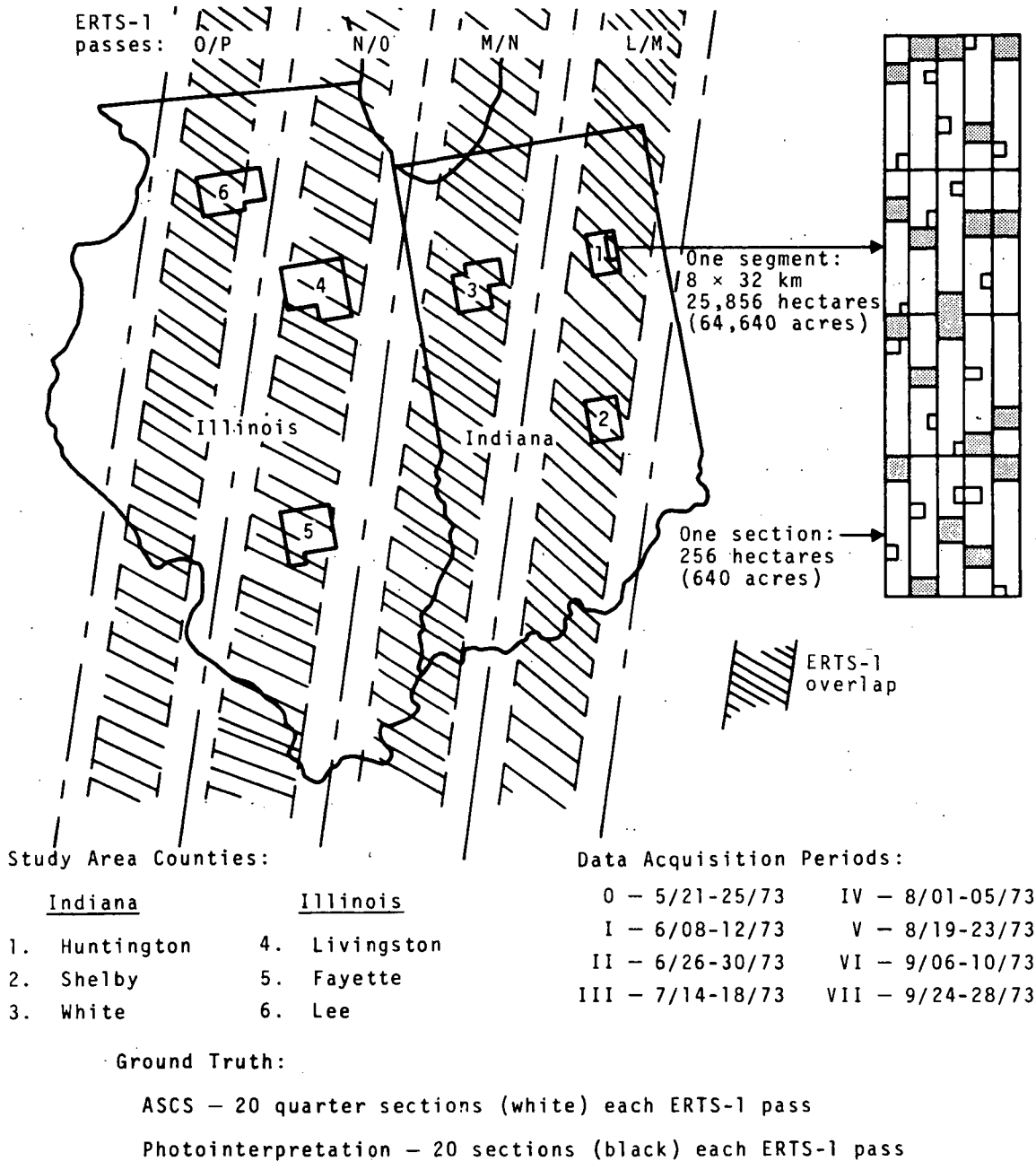


Figure 1.- Technology assessment data set,
May through September 1973.

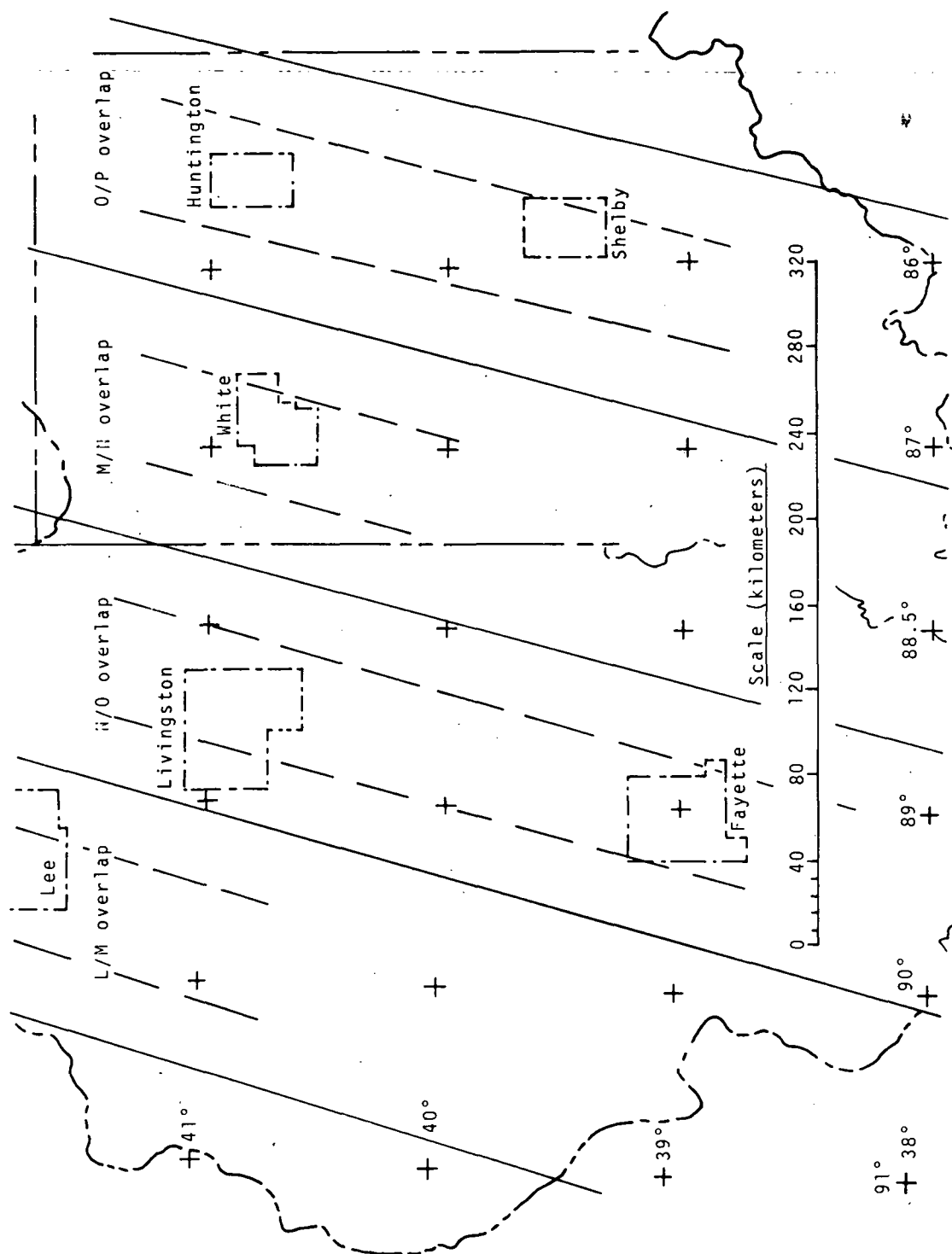


Figure 2.- Map of ERTS-1 ground track positions, December 1972 through February 1973.

4.0 DATA ACQUISITION

Several types of data are required to meet the task objectives:

1. Scanner data from spacecraft and aircraft platforms
2. Aircraft photography from low or intermediate altitudes (These data will be used for crop identification extensions by identifying selected agricultural conditions and by measuring areas and delineating fields in the scanner data.)
3. Ground investigations to provide crop identifications and condition and progress reports on meteorological conditions throughout the period of the experiment
4. High-altitude metric photography for ground-truth annotation and countywide coverage

The ERTS-1 MSS data are acquired at 18-day intervals along each ground track. Both the ground observations and the aircraft support flights are coordinated with ERTS-1 overflights. The dates of overflights during ERTS-1 cycles 16 through 25 are presented in table I. Data acquisition periods have been identified as 0 through VIII, but the acquisition periods of primary interest for ADP processing are periods II through VI (fig. 1). The ASCS field visits and low-altitude aircraft photography were mandatory during periods II through VI. Because of the uncertainties involved in the acquisition of these data, periods I through VII will be analyzed if necessary. The support data schedules could be made more flexible by taking advantage of improved weather conditions.

4.1 SPACECRAFT SCANNER DATA

Both the MSS on the ERTS-1 and the MSS on Skylab should be operational during the data-collection phase of this experiment.

4.1.1 ERTS-1

The scanner mounted on the ERTS-1 collected four-channel data covering a strip 280 kilometers wide on each pass across the United States. Orbital parameters of the ERTS-1 were designed to repeat the coverage along each ground track at 18-day intervals. Because its orbit is Sun-synchronous, the ERTS-1 views an area with similar conditions of illumination on every pass, at approximately 10 a.m. local standard time. This provides an adequate record of temporal changes in the spectral responses of developing crops.

Because weather summaries indicate a high probability of greater than 30 percent cloud cover in this region during the summer months, EOD has acquired bulk, MSS, nine-track, computer-compatible tapes (CCT's) with 314.9 bits/centimeter for MSS frames that include coverage of the test segments. The MSS frames with reported cloud coverage of 70 percent or less were on standing order for ERTS-1 cycles 16 through 24. Frames reported to include greater than 70 percent cloud cover will be screened as microfilm copy arrives. If the test segment (only 1 percent of the frame area) is significantly free of clouds, all CCT coverage of the frame will be ordered. Tapes for frames that provide acceptable coverage of a test segment will be duplicated by JSC for

shipment to LARS. The loss of data from the study area during one 18-day cycle because of cloud cover or malfunction would impair the documentation of temporal changes in crops.

4.1.2 Skylab

The MSS mounted on Skylab collected data over one or more of the test segments during August and September of 1973 for comparison with the ERTS-1 data. Skylab retraced each ground track at intervals of 118 hours; the spacecraft crossed a point on the ground track 12 hours earlier in the day on each successive overflight. The MSS was nominally oriented with the Z-axis to local vertical orientation.

4.2 AIRCRAFT SCANNER DATA

Data from a state-of-the-art, aircraft-mounted MSS are required throughout the period of the experiment to monitor the changes in spectral responses associated with the full cycle of crop development. An aircraft-mounted MSS that covers atmospheric windows in the reflective infrared and thermal infrared regions would be desirable. The inclusion of thermal infrared scanner data in this assessment would increase the reliability of projecting the results of data interpretations from spacecraft scanners that are sensitive to thermal infrared radiation; that is, those on Skylab and those that will be on the second Earth Resources Technology Satellite (ERTS-B).

Data from two other state-of-the-art scanners were required from June through September 1973. These scanners were the modular 11-channel scanner (M²S) developed by The Bendix Corporation and the modular 12-channel scanner (M-7) developed by ERIM. Data from the M²S will be the prime aircraft scanner data source for comparison with the ERTS-1 MSS performance. The CIP obtained by analysis of data from the M-7 scanner will be compared with the M²S and the MSS CIP's to determine the utility of the 1.5 through 2.6 bands (not available on the M²S).

Six data acquisition missions were flown with the M²S and two with the M-7. The schedules for these missions were coordinated as closely as possible with ERTS-1 cycles 19 through 24. Aircraft coverage within 4 days of the last day of each ERTS-1 data acquisition period, with less than 10 percent cloud cover and a Sun angle greater than 40° was highly desirable. Contingency aircraft data acquired within 5 to 8 days after the last day of the ERTS data acquisition period will be acceptable with less than 30 percent cloud cover and a Sun angle greater than 30°. Because scan-angle effects severely degrade recognition accuracy, no more than 50° of the total field of view of scanner data will be processed. Since the aircraft flight lines were required to be parallel to the centerline of the 20-mile length of the segment, two flight lines provided complete coverage of the segment.

4.3 AIRCRAFT PHOTOGRAPHIC DATA

Because a more accurate estimate of the CIP for each ADP technique could be obtained if a larger field sample than that collected by ground investigation were available

from each segment, 20 additional sections in each segment will be collected. With these data, skilled photointerpreters will delineate training and test fields in the scanner data and extend crop identifications from fields observed on the ground to fields in nearby sections. Agricultural conditions such as soil variability, row spacing and orientation, and crop uniformity can be readily evaluated, and temporal changes can be documented. Areas measured on the photographs will permit accurate determination of the proportions of crops in selected groups of contiguous fields.

High-altitude (3,000 to 4,500 meters), color infrared photography covering the six counties was obtained from the RB-57 aircraft with the RC-8 camera, using Kodak 2443 film. This coverage was requested for three periods in 1973:

1. June 8-30 (June 26-30 was considered very favorable.)
2. July 8-25 (July 14-18 was considered very favorable.)
3. August 1-23 (August 19-23 was considered very favorable.)

A Fairchild 224 camera (150-millimeter focal length, 225-millimeter format, Kodak 2443 film) installed on a Bendix Queen Aire will provide an image of adequate resolution from altitudes of 4,500 meters or less. The photographic missions should be scheduled coincidentally with or following the overflights of ERTS-1 cycles 18 through 23 so that the imagery can be used to investigate any anomalies (such as those caused by flooded fields or hail-damaged crops) that were present in the ADP identifications. Cloud cover of less than 10 percent is highly desirable; less than 30 percent is mandatory.

Metric photography for mensuration was mandatory for the missions flown in late June and late August. This photography was acquired with the NASA Zeiss metric camera installed aboard the Michigan C-46 aircraft at ERIM.

4.4 GROUND INVESTIGATIONS

Ground investigations by experienced ASCS field personnel in the six counties will provide the control required for the technology assessment. Two types of data will be collected: agricultural information and atmospheric, optical depth information.

4.4.1 Agricultural Data

Agricultural observations in the 20 quarter sections in each segment are planned to coincide approximately with the ERTS-1 overflights (every 18 days). A plus or minus variance of 24 to 48 hours because of weather or weekend schedules is acceptable. On the first visit to each quarter-section tract, ASCS personnel will mark the boundaries of each field on a base photograph and assign an identification number to each area. Then the crop or land use will be identified, and data concerning cultural practices and crop conditions will be recorded. This will be repeated on subsequent visits, and any changes that occurred since the preceding visit will be noted. The Ground Observations Summary Form (JSC form 1570A) will be used to simplify uniform reporting of ground investigation data (fig. 3).

The crop identifications are required to train the photo-interpreters and to test the classification results.

Periodic reports of the agricultural conditions in fields used for training and testing will be used to supply the data needed to evaluate the probable causes of misclassified points.

4.4.2 Atmospheric Optical Depth Data

Solar radiation will be measured to obtain valuable information about the atmospheric layer between the spacecraft and the surface. A seven-channel solar spectrophotometer built at JSC has been issued to each participating county for this purpose. Observations will be recorded on the form entitled "Optical Depth Observation" (fig. 4). The ASCS crews were requested to take five sets of readings on the day of each scheduled ERTS-1 overflight:

1. One reading in early morning, anywhere in the county
2. Three readings between 9:00 and 10:00 a.m. local time: one from a station in the northern quarter, one from the southern quarter, and one from the middle of the segment (in any order)
3. One reading near solar noon, anywhere in the county

The second group of readings had higher priority than the first or third since they related directly to potential correction of the ERTS-1 MSS data. Timing was critical, inasmuch as weather or scheduling problems could prohibit the taking of readings at scheduled times, thus causing the loss of data.

TABLE I.- ERTS-1 COVERAGE SCHEDULE FOR TEST SEGMENTS

| ERTS-1 cycle | Month | Period | Date of overflight along track | | | | |
|-----------------|-----------|--------|--------------------------------|----|----|----|----|
| | | | L | M | N | O | P |
| 16 | May | | 3 | 4 | 5 | 6 | 7 |
| 17 | May | 0 | 21 | 22 | 23 | 24 | 25 |
| 18 | June | I | 8 | 9 | 10 | 11 | 12 |
| 19 | June | II | 26 | 27 | 28 | 29 | 30 |
| 20 | July | III | 14 | 15 | 16 | 17 | 18 |
| 21 | August | IV | 1 | 2 | 3 | 4 | 5 |
| 22 | August | V | 19 | 20 | 21 | 22 | 23 |
| 23 | September | VI | 6 | 7 | 8 | 9 | 10 |
| 24 | September | VII | 24 | 25 | 26 | 27 | 28 |
| 25 | October | VIII | 12 | 13 | 14 | 15 | 16 |

Counties covered:

| | | | | |
|--|--|-----------------------------|--|-------------------------|
| | <u>L/M</u> | <u>M/N</u> | <u>N/O</u> | <u>O/P</u> |
| | Huntington and Shelby Counties, Indiana | White County, Indiana | Livingston and Fayette Counties, Illinois | Lee County, Illinois |

County _____ Date _____ Observer _____
Township _____ Range _____ Section _____ (NW, NE, SE, SW) Quarter _____

[illegible]

| CROP MATURITY STAGES -- | | Column 5 | Column 6 | Ground Cover |
|-----------------------------|--------------|------------------------------------|---------------|--------------|
| WHEAT | CORN | SOYBEANS | Row Direction | Column 8 |
| 1. Boot | 1. Pretassel | 1. Prebloom | 0 - No rows | 0 - 0-5% |
| 2. Headed | 2. Tasseled | 2. Blooming | 1 - N - S | 1 - 5-20% |
| 3. Turning Yellow | 3. Mature | 3. Early Pod Set | 2 - E - W | 2 - 20-50% |
| 4. Mature | | 4. Late Pod Set | 3 - NW - SE | 3 - 50-80% |
| | | 5. Turning yellow, leaves dropping | 4 - SW - NE | 4 - 80-100% |
| Other | | 6. Mature | 5 - Contour | |
| One or two word description | | | | |

Figure 3.— Ground observations summary form.

[illegible]

Figure 4.— Optical depth observation form.

5.0 DATA HANDLING

To accomplish the CITARS objectives, an experiment must be designed to:

1. Accurately estimate the CIP
2. Determine whether the differences in CIP's for various conditions are significant

Each CIP will be established on the basis of a specific treatment combination characterized by the following factors:

1. Platform-sensor combination:
 - a. ERTS-1 MSS
 - b. Aircraft M²S
 - c. Aircraft M-7
 - d. Aircraft multispectral data system (MSDS)
 - e. Earth Resources Experiment Package (EREP) MSS
2. ADP technique: The 11 techniques are defined in section 5.3.2.
3. Data acquisition period: The six periods of data acquisition are set out in section 4.0. It is anticipated that the levels in this factor will differ when using multitemporal ADP techniques; for example, if data from three passes are used for the analysis, there are 10 possible ways of combining the six data acquisition periods.
4. Location: The six test sites are discussed in section 3.0.

5. Training recognition: Many possible levels exist, but they will be characterized as:
 - a. Local recognition
 - b. Nonlocal recognition

Each treatment combination will have an associated CIP that will be quantified in three ways:

1. The classification performance matrix will be used to determine errors of omission and commission. It will be established by comparing the ADP classification with the ground and photointerpretive identifications of about 5,120 hectares within each data segment. The probability for correct classification of corn, soybeans, wheat, and "other" for a particular test field set will be defined as the frequency with which test field pixels of a particular class are classified correctly. The error of commission between two classes will be defined as the frequency with which an ADP identification of one of the classes is determined from ground truth to have been actually a pixel from the other class. For a four-class data set, this procedure will define a 4-by-4 error matrix.
2. The proportion classification error vector will be established by comparing the proportions of corn, soybeans, wheat, and "other" (determined from the ADP technique) to those proportions determined from photointerpretation and ground truth (sections 4.3 and 4.4).
3. A proportion error vector will be estimated for each treatment based on a proportion vector corrected for bias. The proportion of each crop type in the sections

within each segment will be established by mensuration of the photography. The result will be compared with the proportions established by the ADP techniques to determine the ADP proportion error vector. In addition, several methods have been proposed for correcting the remote sensing estimates of the crop proportions for bias. Each of these methods will require an estimate of the bias, which is obtained by examining the classification performance in pilot fields.

5.1 AIRCRAFT PHOTOGRAPHIC DATA

Aircraft photography will be processed at JSC. Selected frames required for base maps will be printed at the appropriate scale in the required quantities. The JSC interpreters will study, as a minimum, the photographs exposed during the June, July, August, and early September missions before reporting final conclusions. Field boundaries of the areas to be provided with supplemental identifications and some preliminary decisions will be available in August. (Appendix E sets out the procedures for photointerpretation.)

Image interpretation data will include:

1. Outlines of fields to be identified on the base photograph
2. Interpreted identifications of crops in specific fields
3. Determination of the proportions of areas occupied by corn, soybeans, wheat, and "other" in a group of contiguous fields occupying multiple-section blocks
4. Documentation of changes occurring within each field

The accuracy of photointerpretive crop identification procedures will be determined by the test procedure described in appendix B. If the test indicates errors in the photo-interpretation field identifications, the source and nature of the photointerpretive errors will be ascertained, and the effects of these errors on the estimates of the ADP CIP will be assessed.

5.2 GROUND INVESTIGATION DATA

Ground investigation data will be shipped from the ASCS offices to JSC, where they will be assembled. Copies of the crop identification and agricultural practice data for each segment will be transmitted to ERIM and LARS as the ERTS-1 tapes become available. A modified copy of the crop identification data will be distributed to the EOD Image Interpretation Team. Selected quarter-section blocks that have been investigated by the ASCS teams will be concealed from the interpreters as a test set to be used in evaluating the accuracy of identifications from aircraft photography. Great care will be taken to ensure the removal of data for these fields from each set of ground-truth data distributed to the image interpreters. (Appendix F outlines the procedure for testing photointerpretation accuracy.)

5.3 MSS DATA

5.3.1 Data Preparation

Specific procedures will be followed in reformatting the spacecraft and aircraft MSS data and in identifying the section, quarter section, and specific field and field types

from which the data were taken. Each institution involved will use common training and test field boundaries and duplicate spacecraft and aircraft scanner tapes to permit more meaningful performance comparisons and to eliminate the needless duplication of tasks and resources at each institution.

To implement this philosophy, LARS will reformat the ERTS-1 and M-7 scanner tapes into the format of a classification program developed at LARS (LARSYS 3). Modular MSS data will be accepted at JSC and screened and reformatted as necessary. The EOD will reformat the M²S and MSDS pulse-code modulated (PCM) tapes into LARSYS 3 format. Duplicate tapes will be shipped to ERIM and LARS, as required. The M-7 data will be screened by ERIM, and duplicate copies of the analog tapes will be sent to LARS and EOD. LARS will then select the field boundaries on all the tapes for use at each institution. (See fig. 5 for data flow, appendix G for data screening and evaluation procedures, and appendix H for data preparation procedures.)

5.3.1.1 ERTS-1 data.-- ERTS-1 bulk data tapes will be received from the Goddard Space Flight Center (GSFC) by EOD personnel for duplication at JSC. During the duplicating activity, the tapes will be visually screened on a cathode-ray tube (CRT) color display, using various combinations of three of the four bands to obtain and record the following:

1. Quick-look band-by-band data quality
2. General location of the segment by line and column count and extent of coverage within the CCT
3. Degree of cloud coverage over the segment

Of the two data passes over each segment, the one acquired during minimum cloud cover will be selected for local recognition. If cloud cover is equal for the two passes, the data acquired most temporally coincident with the ASCS field visit will be chosen for local recognition processing.

The duplicated tapes will be forwarded to LARS for subsequent reformatting and field boundary definition. The LARS will then send duplicate copies and field coordinates of the reformatted tapes to EOD and ERIM for data analysis processing.

5.3.1.2 EREP scanner data.-- Some EREP MSS data may have been acquired over the technology assessment segments. If so, these data will be analyzed for CIP and compared with CIP's obtained in other trials. The exact procedures used to accomplish this task will not be defined until the nature and quality of these data are known.

5.3.1.3 Aircraft scanner data (M²S, M-7, MSDS).-- The data from each aircraft scanner pass over each segment will be examined for quality (appendix G). If found acceptable, the data will be reformatted to LARSYS 3 format, and the training and test field boundaries will be selected at LARS. Copies of the field coordinates for each aircraft tape will be sent by LARS to EOD and ERIM to ensure that each institution is using identical test and training data and to eliminate the needless duplication of the resources required to select field boundaries.

5.3.2 Data Processing

Each of the 11 ADP techniques will be used to process reformatted duplicate data (discussed in section 5.3.1 and in appendix H) for each scanner data source. Each technique consists of a computer-implemented software system and a method or procedure by which MSS data can be converted into ground-cover class identification information on a pixel-by-pixel basis.

The CIP of ADP techniques can be sensitive to the manner in which the classifier is trained, the types of MSS input data (for example, preprocessed, multitemporal), the spectral bands which are used for recognition, and so forth. Most of the existing procedures for the use of very generalized analysis algorithms require decisions on the part of the analyst; these decisions also can significantly affect the classification performance obtained.

A quantitative evaluation and subsequent comparison of the CIP's of the ADP techniques will be most meaningful if the procedures used to obtain the classification results are well defined and repeatable. Therefore, each of the ADP techniques evaluated in this task will be documented in detail (appendix I), and the documented procedures will be observed rigidly to reduce variations in the classification repeatability of an ADP technique. Any proposed deviation from these procedures must have the prior approval of the Technical Advisory Team described in section 6.0.

Each ADP technique to be evaluated is described in general terms in the following discussion (for more detail, see appendixes J, K, and L). The techniques are grouped

into three categories: standard, preprocessing for signature extension, and processing for multitemporal and unresolved objects. A code is used to distinguish each technique with regard to:

1. The data source: ERTS or aircraft
2. The Institution: EOD, ERIM, or LARS
3. The processing technique: standard processing (SP), preprocessing and standard processing (PSP), multitemporal processing (MSP), or unresolved objects processing (UP)

5.3.2.1 Standard ADP techniques. - These techniques use either Gaussian maximum likelihood classifiers or classifiers using a linear decision rule. They classify data which have not been radiometrically preprocessed or acquired multitemporally.

5.3.2.1.1 ERTS-LARS-SP1: A combination of manual and automatic clustering techniques is used to identify spectral subclasses, which are assumed to have equal *a priori* probabilities. These subclasses are used to compute the training statistics required by the maximum likelihood classification algorithm. This algorithm is a standard part of the LARSYS 3 program.

5.3.2.1.2 ERTS-LARS-SP2: This technique is similar to ERTS-LARS-SP1, except that SP2 includes a procedure for estimating the relative proportions of the object crops from field data and a procedure and software for using these proportion estimates as *a priori* probabilities in the decision algorithm. In the early portion of the technology assessment effort, LARS will conduct statistical tests to determine the best of SP1 and SP2 with respect to CIP. If SP2 proves to

be more accurate, it may replace SP1 for the remainder of the assessment.

5.3.2.1.3 Aircraft-LARS-SP1/SP2: These techniques differ from ERTS-LARS-SP1/SP2 in only one respect: Feature selection will be used to select the best subset of the available spectral channels based on the LARSYS 3 separability processor.

5.3.2.1.4 ERTS-ERIM-SP1: A classification algorithm is used to apply best linear decision boundaries between classes, as opposed to the quadratic decision boundaries applied by the other conventional algorithms to be tested. Each major crop will be represented by a single multivariate Gaussian distribution function (selected by choice for this proceduralized technique). Additional signatures will be determined only for those "other" classes of training data that are likely to be misclassified as one of the major crops.

5.3.2.1.5 ERTS-ERIM-SP2: A maximum likelihood classifier (quadratic rule) is used in place of the best linear decision rule. Otherwise, this technique is similar to ERTS-ERIM-SP1.

5.3.2.1.6 ERTS-EOD-SP1: The training field data for corn, soybeans, and wheat will be preprocessed by independent runs of the EOD Iterative Self-Organizing Clustering System (ISOCLS) on the Earth Resources Interactive Processing System (ERIPS) at JSC. The ISOCLS routine will generate class and, if necessary, subclass statistics; that is, corn 1, corn 2, and corn 3. The training fields for "other" will then be

submitted to the same clustering scheme to generate class and subclass statistics for all "other." The training field, test field, and test section data will then be classified using the Gaussian maximum likelihood classification algorithm on ERIPS to process the statistics previously generated with the clustering process.

5.3.2.2 ADP techniques with preprocessing for signature extension.- Before nonlocal recognition is accomplished, both ERTS and aircraft MSS data will be preprocessed by ERIM to stabilize signature variations that result from variations of incident solar and sky illumination. Before local recognition is attained, both EOD and ERIM will preprocess aircraft data with the ERIM-developed procedure for reducing variations in aircraft signatures that result from scan-angle-dependent variations in atmospheric and target characteristics.

5.3.2.2.1 ERTS-ERIM-PSP1: Preprocessing will correct for average differences between the training segment and each nonlocal recognition segment. An adjustment will be made by adding to each channel mean the difference between the mean signal in the test segment and the mean signal in the training segment. Covariance matrices will remain the same. Scan-angle effects in ERTS data over the test segments are considered negligible, so scan-angle preprocessing will not be applied. After preprocessing, recognition processing will be accomplished as described under ERTS-ERIM-SP1 (section 5.3.2.1.4).

5.3.2.2.2 Aircraft-ERIM-PSP2: This technique will correct for scan-angle effects in aircraft data before any

recognition is performed. An algorithm, ACORN4 will be used to correct data for scan-angle-dependent variations before classification. A correction function will be derived for each channel by computing the average signal versus the scan angle over the quarter sections visited by the ASCS. The result will be normalized to the value at some reference angle. The tape data will be preprocessed by dividing the signal values by the corresponding values of the correction function. In those instances where two adjacent passes are made over a single segment, a multiplicative adjustment of corrections for one pass will be made to produce the same mean levels in both passes after correction.

After the correction procedure is completed, training signatures will be extracted in a manner similar to that for ERTS-ERIM-SP1 (section 5.3.2.1.4). A subset of channels will then be selected; these are required by a classification algorithm that uses the average probability of misclassification as its performance measure. Following channel selection, recognition processing will be accomplished using a procedure similar to that for ERTS-ERIM-SP1 (section 5.3.2.1.4).

5.3.2.2.3 Aircraft-ERIM-PSP3: This technique will process aircraft MSS data for nonlocal recognition. The procedure is the same as for aircraft-ERIM-PSP2, except for the addition of a multiplicative adjustment of signatures to account for variations between segment signatures. It will exclude thermal channels from the channel selection process, based on the hypothesis that thermal data will not vary consistently from one segment to another. (The thermal histories of segments can be expected to differ.)

5.3.2.2.4 Aircraft-EOD-PSP1: This technique will be used when a linear combination of features for subsequent classification processing is required. The preprocessing algorithm and procedure to be used are described in the aircraft-ERIM-PSP2 technique. An EOD clustering procedure similar to the one used in ERTS-EOD-SP1 (section 5.3.2.1.6) will be used to extract training signatures. Feature selection will be accomplished with an algorithm developed by the University of Houston. The EOD will classify the data using linear combinations of features and the maximum likelihood algorithm.

5.3.2.3 ADP techniques for multitemporal and unresolved objects.- These data classification techniques will be employed as required.

5.3.2.3.1 ERTS-EOD-MSPl: The training and test field boundary coordinates selected for unitemporal processing may not be valid for the multitemporal data set, as in the case of an incompletely harvested field. This technique will classify, by registration, the combination of two or more ERTS data sets acquired over a common segment during two or more data acquisition periods. A clustering procedure will be used to separate spectral classes. A linear combination of features will be selected using an EOD algorithm, and the classification will be executed by the maximum likelihood algorithm.

5.3.2.3.2 ERTS-ERIM-SP3: An algorithm will be used to estimate the proportions of unresolved objects within pixels of the ERTS data. Therefore, in principle, this technique should be more accurate than conventional algorithms in estimating the proportions of major crops in larger areas

containing boundary pixels which represent mixtures of signals from two or more materials. Since this technique requires linearly independent class signatures (five at most with four ERTS bands), a test of this independence will be applied before the algorithm is employed.

5.4 PERFORMANCE COMPARISONS

In section 2.0, eight questions are listed that must be answered before the CITARS demonstration can be successful. These are rephrased here into 12 basic questions that are amenable to answer by a series of analyses of variance, as described in section 5.5. Each question (except number 11) refers to one of the major factors thought to affect performance. Question 11 asks about the effects of combinations of these factors.

1. What level of local recognition for CIP can be achieved by selected standard ADP techniques using spacecraft-acquired data? Are any of the observed differences in CIP's significant with respect to ADP techniques?
2. What CIP's can be expected at specific stages of crop maturity? Are any significant differences in CIP's observed with respect to growing seasons?
3. How do CIP's vary with respect to geographic locations having different soil, weather, management practices, crop distributions, and field sizes? Are any significant differences in CIP's observed with regard to geographic location?
4. What level of CIP can be achieved from the use of aircraft MSS data? Are any of the observed differences in

CIP's significant when spacecraft and aircraft data are compared? These questions must be answered also for each of the following specific conditions:

- a. When aircraft data are not restricted
 - b. When aircraft data are limited to ERTS-1 bands
 - c. When aircraft data are limited to ERTS-B bands
5. How do signature variations resulting from physical factors such as geographic location, growing season differences, and meteorological changes affect the ability to extend signatures?
- a. Does the spacecraft CIP obtained by local recognition for segments acquired during one ERTS orbit differ significantly from the local recognition CIP obtained by training on a segment with its classification on a succeeding ERTS orbit?
 - b. Does the spacecraft CIP obtained by local recognition differ significantly from the CIP obtained by nonlocal recognition during the same ERTS orbit?
 - (1) List significant differences between the CIP for local training/nonlocal recognition and the CIP for nonlocal recognition.
 - (2) List significant differences between the CIP of nonlocal recognition from data taken in east-to-west orbit and the CIP of nonlocal recognition from data taken in north-to-south orbit.
 - c. Does the spacecraft local recognition CIP obtained by training on and recognizing a segment during one ERTS orbit differ significantly from the CIP obtained

- by training on a segment and classifying it during succeeding ERTS data acquisition periods?
- d. Does the spacecraft CIP obtained over several segments by local recognition differ significantly from the CIP obtained by pooled training on the same segments and their subsequent recognition?
 - e. Does the spacecraft CIP obtained by nonlocal recognition over several ERTS orbits differ significantly from the CIP obtained by local recognition?
 - f. Does the aircraft local recognition CIP differ significantly from the aircraft nonlocal CIP when the data acquired are processed on the same day? Do the variations observed in north-to-south orbit differ significantly from those observed in east-to-west orbit?
- 6. How do the different forms of preprocessing affect the CIP's for local and nonlocal recognition?
 - 7. Does classification using multitemporal data significantly improve CIP?
 - 8. How does the proportion error vector for areas excluding field boundaries compare to that for areas including boundaries?
 - 9. How do the CIP results differ when the training set selection varies?
 - 10. What effects do geometric correction and registration have on CIP?
 - 11. How is CIP affected by various combinations of the factors described in questions 1 through 10?

12. Does CIP differ significantly when data are obtained from aircraft scanners such as the Bendix M²S, the ERIM M-7, and the NASA MSDS?

See analyses I through XI, appendix L, for methods of responding to the above questions.

5.5 EVALUATIONS OF CIP

5.5.1 Determination of Significant Differences in CIP's

Once the CIP's are computed, they form the basis for comparing the achievements of the techniques under the various conditions. These comparisons will be made using standard statistical tests, primarily the analysis of variance, to determine whether the classification performances for two or more different treatments (or combinations of treatments) are different. Various hypotheses will be formulated and tested for each factor.

An example of a hypothesis to be tested is: "No significant differences in CIP's exist among test sites." To test this hypothesis, the ratio of variation among test sites is compared to the variation within test sites. This ratio, which is referred to as the calculated F , is the ratio of the treatment mean square (among) to the error mean square (within). If the calculated F is greater than the tabulated F based on the known distribution of the variance ratio under the null hypothesis, then the null hypothesis would be rejected; and the alternate hypothesis that the performances are different for different locations would be accepted.

To use the analysis-of-variance test, a measure of error must be available. This is obtained from replication that is readily available in a factorial experiment. For example, one assumed mathematical model is

$$\chi_{ij} = \mu + \tau_i + \epsilon_{ij} \quad (1)$$

where

$$i = 1, 2, \dots, k$$

$$j = 1, 2, \dots, n$$

This model states that any observed value χ_{ij} is equal to the overall mean μ for all populations, plus the deviation τ_i of the i th population mean μ from the overall mean, plus ϵ_{ij} , a random deviation from the mean of the i th population. In other words, if μ_i is the mean of the i th population, and K is the total number of populations, then

$$\mu = \frac{\text{sum of } \mu_i}{K} \quad (2)$$

$$\tau_i = \mu_i - \mu \quad (3)$$

and

$$\epsilon_{ij} = \chi_{ij} - \mu_i = \chi_{ij} - \mu - \tau_i \quad (4)$$

for this model, μ is assumed to be an unknown parameter, τ_i represents unknown constants or parameters, and ϵ_{ij} is normally and independently distributed with mean zero and

variance σ^2 . With estimates of the population mean and variance σ^2 , the magnitude of treatment effects can also be estimated, and the confidence interval can be calculated.

5.5.2 Measures of Performance Using ADP Techniques

As discussed in section 3.0, two basic quantities will be used to characterize the CIP using the ADP techniques: One, e_{ij} , is the estimated probability of classifying a pixel from class i as class j ; the other, $\hat{p}_i - p_i$, is the estimated proportion of class i (\hat{p}_i) minus the true proportion of class i (p_i).

In order to compute e_{ij} from the ADP results, pixels which correspond to ground cover classes i and j must be located with respect to known points in areas where ground truth is known. For ERTS data, this presents a formidable problem. Therefore, test fields will be chosen to exclude agricultural field boundaries within pixels and to exclude known field inhomogeneities such as flooded areas. The established e_{ij} will represent the classification error resulting from these pure test pixels.

Some method will be required to estimate the classification error resulting from pixels containing agricultural field boundaries (boundary pixels) and the error resulting from field inhomogeneities, since these errors could represent a large part of the total error in an actual remote sensing situation. The use of e_{ij} to accomplish this is considered impractical because of the difficulty in locating the pixels containing field boundaries. Therefore, the proportion estimate discussed in section 3.0 will be used to

characterize this error. Thus \hat{p}_i will be computed for pure test pixels as well as for the agricultural sections, and the differences in the resulting proportion error vectors will be used to estimate the error contribution resulting from boundary pixels and field inhomogeneities.

5.5.2.1 Factorial analyses for performance comparisons.

Some attempt will be made to correct the proportion estimates \hat{p}_i for the statistical bias that is expected to result from misclassification. The three methods proposed for accomplishing this are:

$$\hat{p}_i = n_i/N$$

$$\hat{p}_i = \beta_i n_i/N$$

or

$$\hat{p}_i = \frac{1}{N}E - \frac{1}{n} \quad (5)$$

where

n_i = number of pixels classified as i

N = total number of pixels in area to be classified

β_i = regression coefficient obtained by comparing n_i/N with the true proportion p_i for pilot data

E = matrix of e_{ij} 's obtained from pilot data (The quantities e_{ij} will be estimated by counting the number of pixels from class i that were classified as class j and dividing by the total number of pixels from class i .)

n = vector of n_i 's

The methods set out in equations 4 and 5 require the use of pilot data; that is, additional ground-truth data used to

obtain estimates of E or β_i . The \hat{p}_i corrected with each method will be compared to the \hat{p}_i determined from the photointerpretation to ascertain if any of the methods improve the proportion estimates.

5.5.2.2 Analysis of variance.- One dependent variable per segment for each of the 20 test areas will be calculated. Once a dependent variable is determined, a typical analysis will include computing the cell means of the dependent variable for various combinations of factors and then performing an analysis for each combination. The various analyses to be performed range from I to XI. Each analysis is designed to answer one or a combination of the various questions set out in section 5.4. Table II lists the questions, their subjects, and the corresponding analysis that responds to each question, either alone or combined with other questions. All analyses respond to question 11, the combination of factors, except analysis X, which refers only to the geometric correction and registration of the CIP. See appendix L for a more complete description of each combination of factors and the resulting analysis.

TABLE II.— PERFORMANCE COMPARISONS BY
ANALYSES OF COMBINATIONS OF FACTORS

| Question | Subject | Analysis reference |
|----------|--|--|
| 1 | ADP standard techniques | I, II, IV-A, V-A, V-B, VIII, XI |
| 2 | Times (stages of crop maturity and growing seasons) | I, II, III-A, IV-B, IV-C, V-A, V-B, VI, VIII, IX |
| 3 | Geographic locations and associated practices and physical factors | I, II, IV-B, IV-C, V-A, V-B, VI, VIII |
| 4 | Aircraft MSS data | V-A, V-B, VI, XI |
| 5 | Local and nonlocal recognition | III, IV-A, IV-B, IV-C, VII |
| 6 | Preprocessing | III-A, III-B |
| 7 | Multitemporal data | VII |
| 8 | Field boundary errors | VIII |
| 9 | Training set selection | IX |
| 10 | Geometric correction and registration | X |
| 11 | Combination of various factors | I, II, III, IV, V, VI, VII, VIII, IX, XI |
| 12 | Aircraft M ² S, M-7, and MSDS | XI |

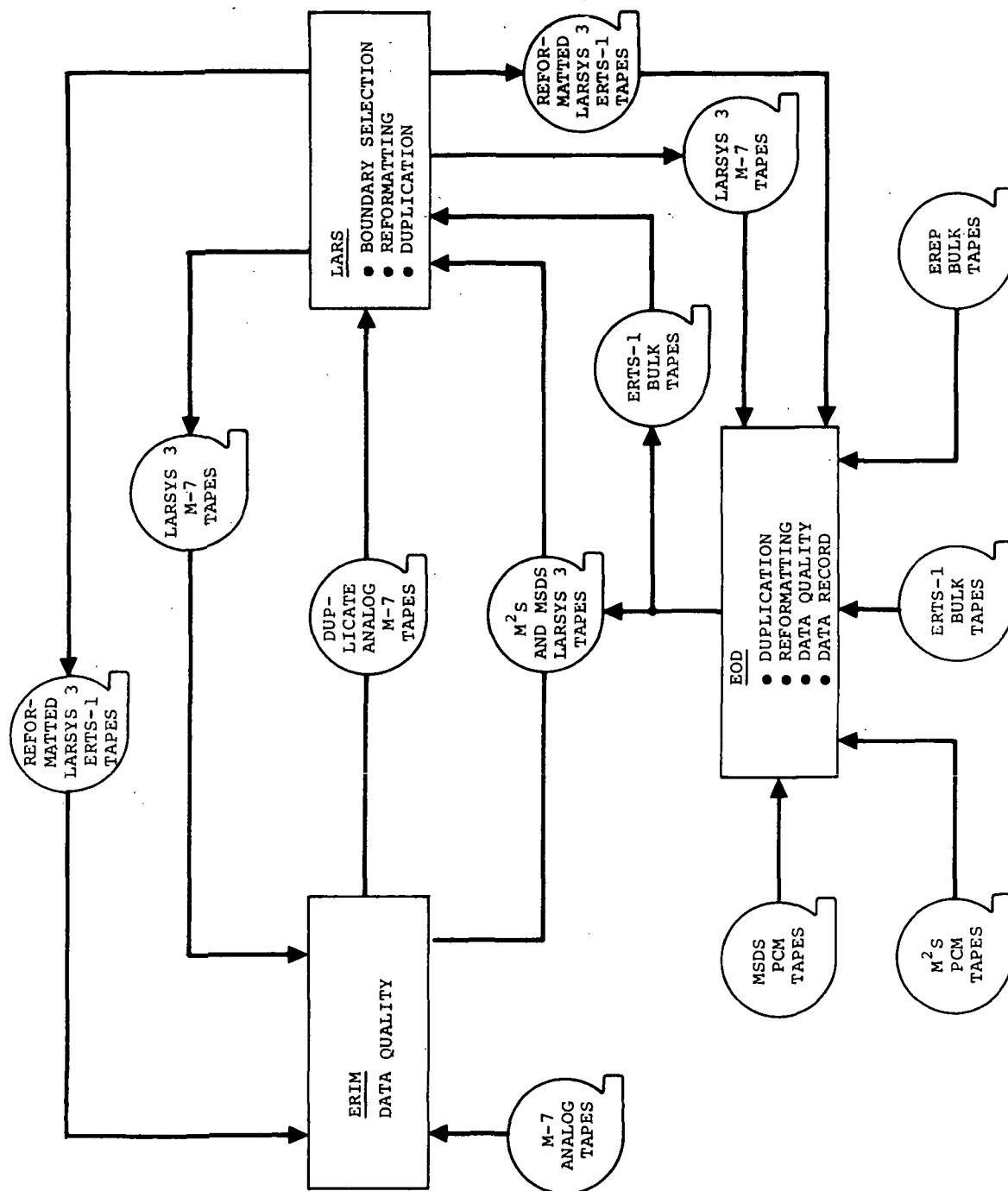


Figure 5.-- Scanner data flow.

6.0 TASK MANAGEMENT

The major participants in the execution of this task will be EOD, ERIM, GSFC, LARS, and USDA. Each has capabilities which represent necessary and unique contributions to the technology assessment of CITARS. Figure 6 sets out the responsibilities of each organization in the performance of the task.

6.1 TASK RESPONSIBILITY

6.1.1 EOD

The EOD at JSC has the prime responsibility for coordinating the various major task areas with each institution, organization, and/or agency involved. The Applications Analysis Branch at JSC will work closely with the EOD SRT team to ensure that adequate communication exists among LARS, ERIM, and EOD. It will likewise assure that the technology assessment task is being coordinated with other related SRT tasks being conducted at LARS, ERIM, and EOD. Figure 7 sets out the responsibilities of the various organizations in connection with the Applications Analysis Branch effort. This structure is designed to provide optimal interplay among the various organizations and institutions and between the techniques development and technology assessment efforts at each.

Certain EOD personnel will be responsible for major task areas in the project. Figure 8 illustrates the project management personnel and the respective area of responsibility of each person or group.

6.1.2 ERIM

The ERIM is responsible for the Assessment of Remote Sensing Techniques for Agriculture task within the Research and Technology Operational Plan (RTOP) task entitled *Techniques Development for Multispectral Scanner Imagery*.

Figure 9 shows the ERIM personnel and the respective area of responsibility of each person in the performance of the technology assessment task.

6.1.3 LARS

The LARS is responsible for the Assessment of Remote Sensing Techniques for Agriculture task within the RTOP task entitled *Applications Development and Techniques Assessment for Remote Sensing Technology*. Figure 10 shows the ERIM personnel and the respective area of responsibility of each person in the performance of the technology assessment task.

6.1.4 GSFC and USDA

As set out in figure 6, the primary responsibilities of GSFC and USDA will be the acquisition of ERTS data and ASCS ground data, respectively.

6.2 SCHEDULE AND MILESTONES

The milestone chart in figure 11 outlines the major milestones for four task areas for operation of the task schedule. Figures 12 through 15 describe the major task areas in detail.

6.2.1 Data Acquisition and Dissemination

The period of data acquisition is from June 8, 1973, through January 1, 1974. This task area involves the photo-interpretive efforts, the acquisition of aircraft and spacecraft scanner and photographic data, the acquisition of ASCS field identification data, the dissemination of the aircraft and spacecraft scanner data, and the interpretive and ASCS ground-truth data annotated on base photography. The milestone schedule shown in figure 12 assumes aircraft and spacecraft scanner and photographic data acquisition beginning June 26 and continuing through September 28.

6.2.2 Establishment of Classification Accuracy

According to the milestone schedule (fig. 11), the periods for establishing classification accuracy are:

1. For spacecraft, August 1, 1973, through February 1, 1974
2. For aircraft, August 1, 1973, through April 15, 1974

Figure 13 gives the schedules for spacecraft and aircraft data processing for each ADP technique. The ERTS data will be processed before the aircraft data, indicating a higher priority for the evaluation of spacecraft data.

6.2.3 Performance Comparisons

The performance comparison analyses discussed in section 5.0 will be made from September 1, 1973, through June 1, 1974. The completion dates for the various comparisons are indicated in figure 14. The spacecraft

performance comparisons will be of highest priority and should be completed by March 1, 1974. Aircraft data performance analyses and aircraft/spacecraft comparisons should be completed by June 1, 1974.

6.2.4 Review and Documentation

Figure 15 details the schedule for the completion of the various reviewing and reporting functions associated with the technology assessment task. The first item, monthly reviews to EOD management, will consist of oral and written status reports on the major milestone areas, with milestone completion problems flagged and with potential solutions proposed for decision by management. Such reviews will be presented quarterly to the Earth Resources Program Office (ERPO). A rough draft of all results obtained by March 1 will be available by mid-March. This document will serve as a review document and will contain most of the spacecraft data performance comparisons. The final document, including both spacecraft and aircraft data and their comparisons, will be available October 1, 1974.

6.3 RESOURCE REQUIREMENTS

This section details the manpower requirements, the aircraft coverage required to acquire the technology assessment data, the data processing requirements for ADP techniques, and the support required for LARS and ERIM. Resource requirements are given in detail in tables III through VII. The resource area to which each table refers is as follows.

| <u>Table</u> | <u>Requirement</u> |
|--------------|---|
| III | EOD manpower |
| IV | ERIM manpower |
| V | LARS manpower |
| VI | Aircraft flights for scanner and photographic coverage |
| VII | Data processing |

Table VII sets out the data processing requirements for EOD, ERIM, and LARS in the following manner: The first column indicates the ADP technique, and the second and third columns give the number of analysis runs for local and non-local recognition. This distinction is made because more resources are required for local than for nonlocal recognition runs. Because nonlocal recognition simply involves a classification run using existing statistics for some local recognition run, less manpower is required for processing. Figure 16 indicates the EOD computational requirements to process the runs shown in table VII.

TABLE III.— EOD MANPOWER RESOURCE REQUIREMENTS

| Function | Manning | | Duration of effort, months | |
|--|---------------|------------------|----------------------------|------------|
| | Civil service | Contractor | Civil service | Contractor |
| Project management | 1.0 | 0.0 | 16.0 | 0.0 |
| Data acquisition and handling | 1.0 | 0.0 | 6.0 | 0.0 |
| Data interpretation/ground-truth extension | 0.5 | 3.0 | 6.0 | 6.0 |
| Data processing | 4.5 | 1.0 | 12.0 | 3.0 |
| Data analysis | 0.0 | 1.0 ^a | 0.0 | 6.0 |
| Documentation | 1.0 | 2.75 | 16.0 | 4.0 |
| Indirect EOD support | 3.65 | 7.5 | LOE ^b | LOE |

^aSummer faculty.^bLevel of effort.

TABLE IV.— ERIM MANPOWER RESOURCE REQUIREMENTS

| Function | Full-time equivalents | Classification |
|-----------------------------------|-----------------------|---|
| Project management | 0.4 | Professional |
| Data handling and analysis | 1.8 | Professional |
| | 0.7 | Student, part-time |
| Statistical design and evaluation | 0.5 | Professional |
| | 0.1 | Student, part-time |
| Documentation | 0.8 | Professional |
| Project support | 1.2 | Administration, secretarial, and publications |

TABLE V.— LARS MANPOWER RESOURCE REQUIREMENTS

| Function | Man-years | Classification |
|------------------------|-----------|---------------------------|
| Project management | 0.6 | Professional and academic |
| Data handling | 0.7 | Professional and academic |
| | 1.5 | Graduate student |
| | 0.4 | Undergraduate student |
| Data analysis | 1.9 | Professional and academic |
| | 2.5 | Graduate student |
| | 2.7 | Undergraduate student |
| Statistical evaluation | 0.4 | Professional and academic |

TABLE VI.— AIRCRAFT RESOURCE REQUIREMENTS

| Requirement | Flight line, km | Mission coverage |
|---|--------------------|---|
| Low-altitude (4.6 km) coverage for large-scale photography for photointerpretation and acquisition of M ² S scanner data | 19.2, 32.0 | Six at 18-day intervals, June-September |
| Low-altitude (4.6 km) coverage for large-scale metric photography for mensuration and acquisition of M-7 scanner data | 19.2, 32.0 | Two during June and August |
| High-altitude (18.3 km) coverage for metric photography for base photographs and countrywide coverage | 28.8, 40.0 | Three during June, July, and late August or early September |

TABLE VII.— CLASSIFICATION PROCESSING RUNS BY ORGANIZATION
AND TECHNIQUE

| Data source/ organization ADP technique | Classification runs | | Remarks | Total runs |
|---|----------------------|-------------------------|--|---------------|
| | Local recognition | Nonlocal recognition | | |
| Aircraft | | | | |
| M ² S-LARS-SP1 | 12 | | } Evaluation of SP1 versus SP2 | 12 |
| M ² S-LARS-SP2 | — | | | |
| M ² S-LARS-SP1 or -SP2 | 18 | 6 | | 24 |
| M ² S-ERIM-PSP2 | 9 | 6 | } No effect on local recognition | 15 |
| M ² S-ERIM-PSP3 | — | 6 | | 6 |
| M ² S-EOD-SP1 | 10 | 6 | | 16 |
| M ² S-EOD-SP2 | 4 | — | | 4 |
| M ² S-EOD-SP3 | 4 | — | | 4 |
| M ² S-EOD-PSP1 | 3 | 6 | | 9 |
| Total | 60 | 30 | | 90 |
| Spacecraft | | | | |
| ERTS-LARS-SP1 | 8 | — | Correction-registration test | 8 |
| ERTS-LARS-SP1 | 12 | — | } Evaluation of SP1 versus SP2 | 12 |
| ERTS-LARS-SP2 | | | | |
| ERTS-LARS-SP1 or -SP2 | 30 | 40 | Establishment of CIP, local recognition; 5 passes and 2 training sets (12 runs) | 70 |
| ERTS-ERIM-SP1 | 24 | 10 | } No effect on local recognition | 34 |
| ERTS-ERIM-PSP1 | — | 10 | | 10 |
| ERTS-EOD-SP1 | 30 | 10 | } Registration processing required | 40 |
| ERTS-EOD-MSP1 | 8 | 4 | | 12 |
| Total | 112 | 74 | | 186 |

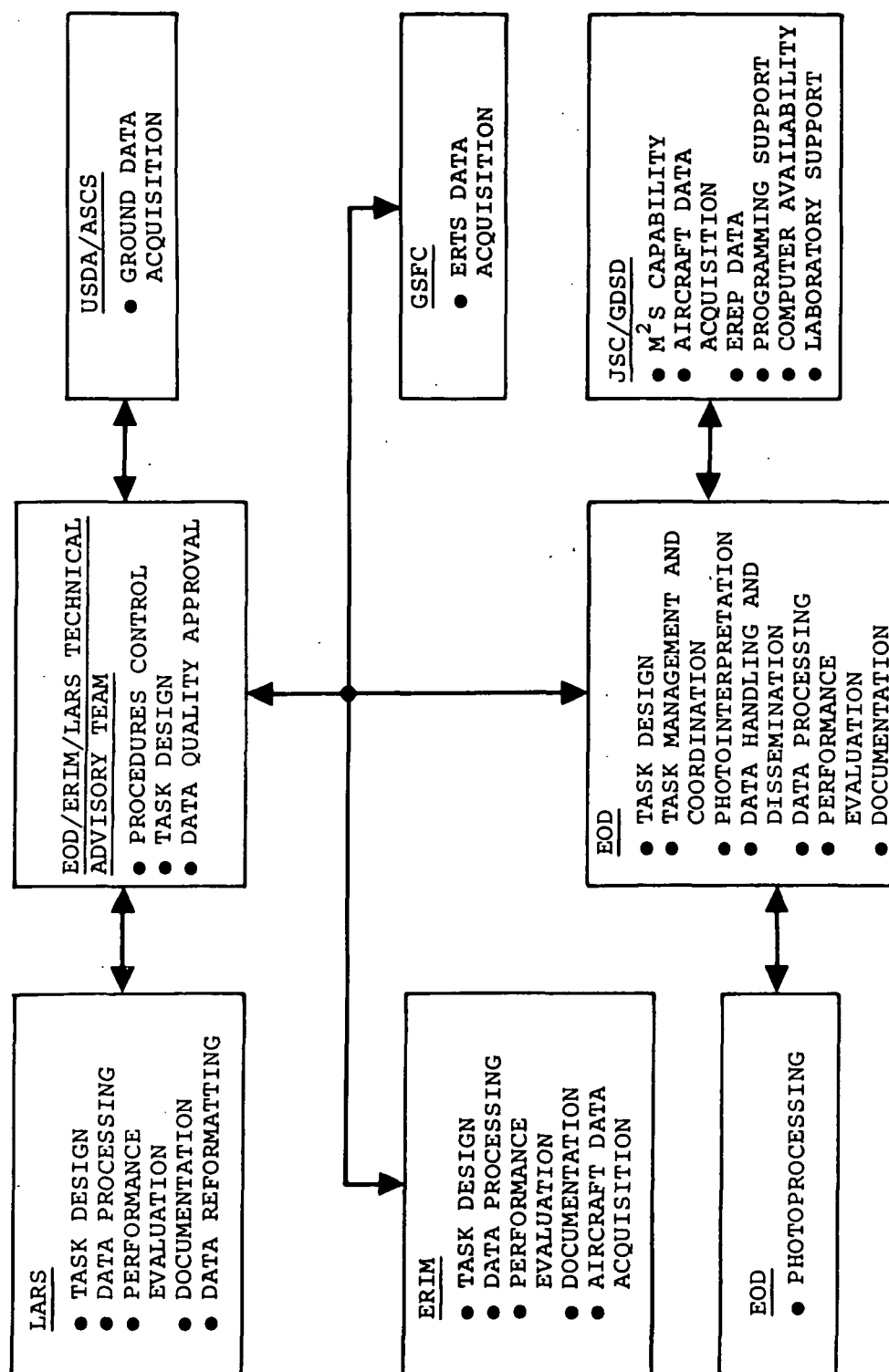
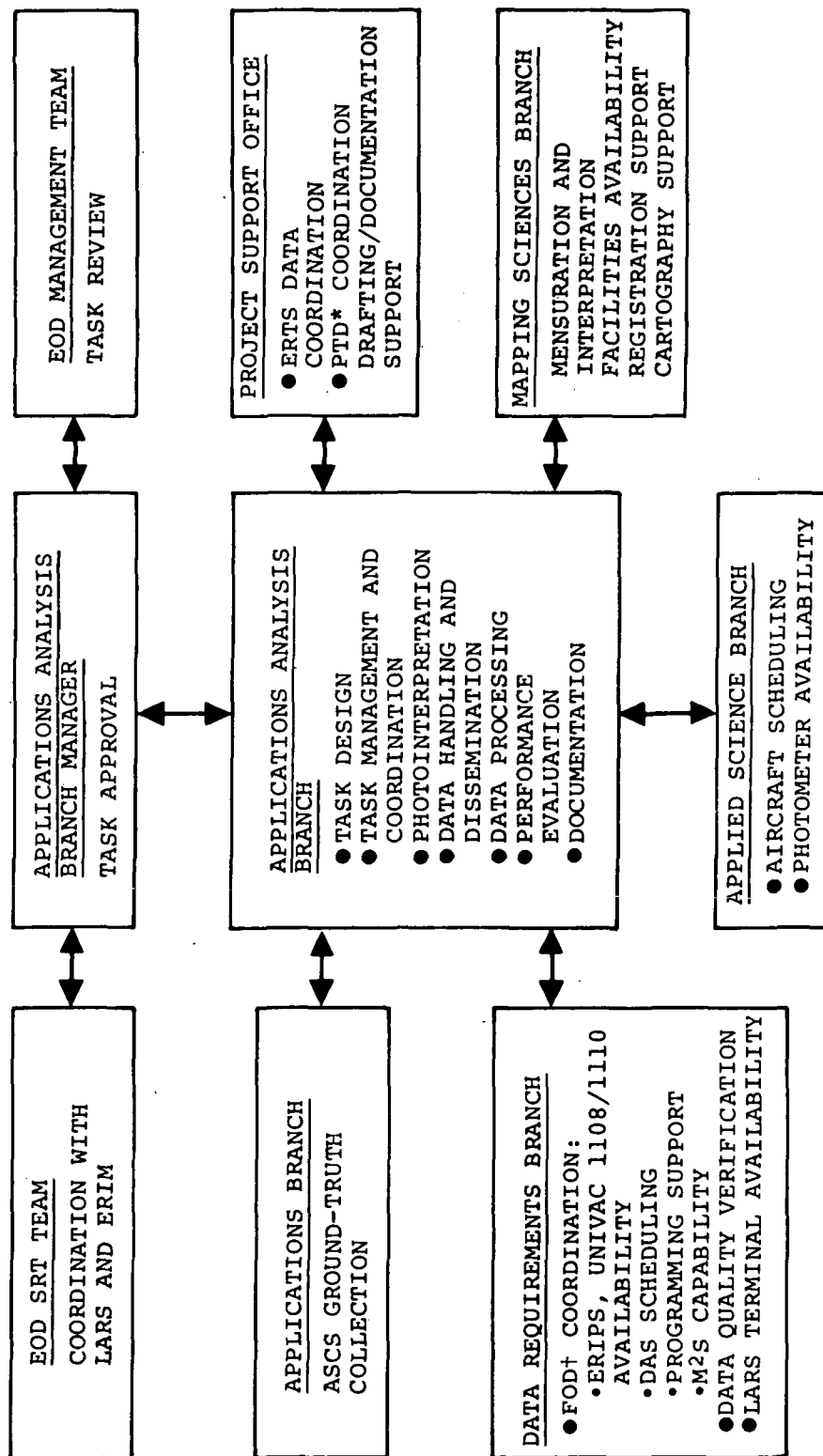


Figure 6.-- Diagram of organizational responsibilities for the CITARS task.



*Photographic Technology Division.

+Flight Operations Directorate.

Figure 7.— Diagram of organizational responsibilities within EOD.

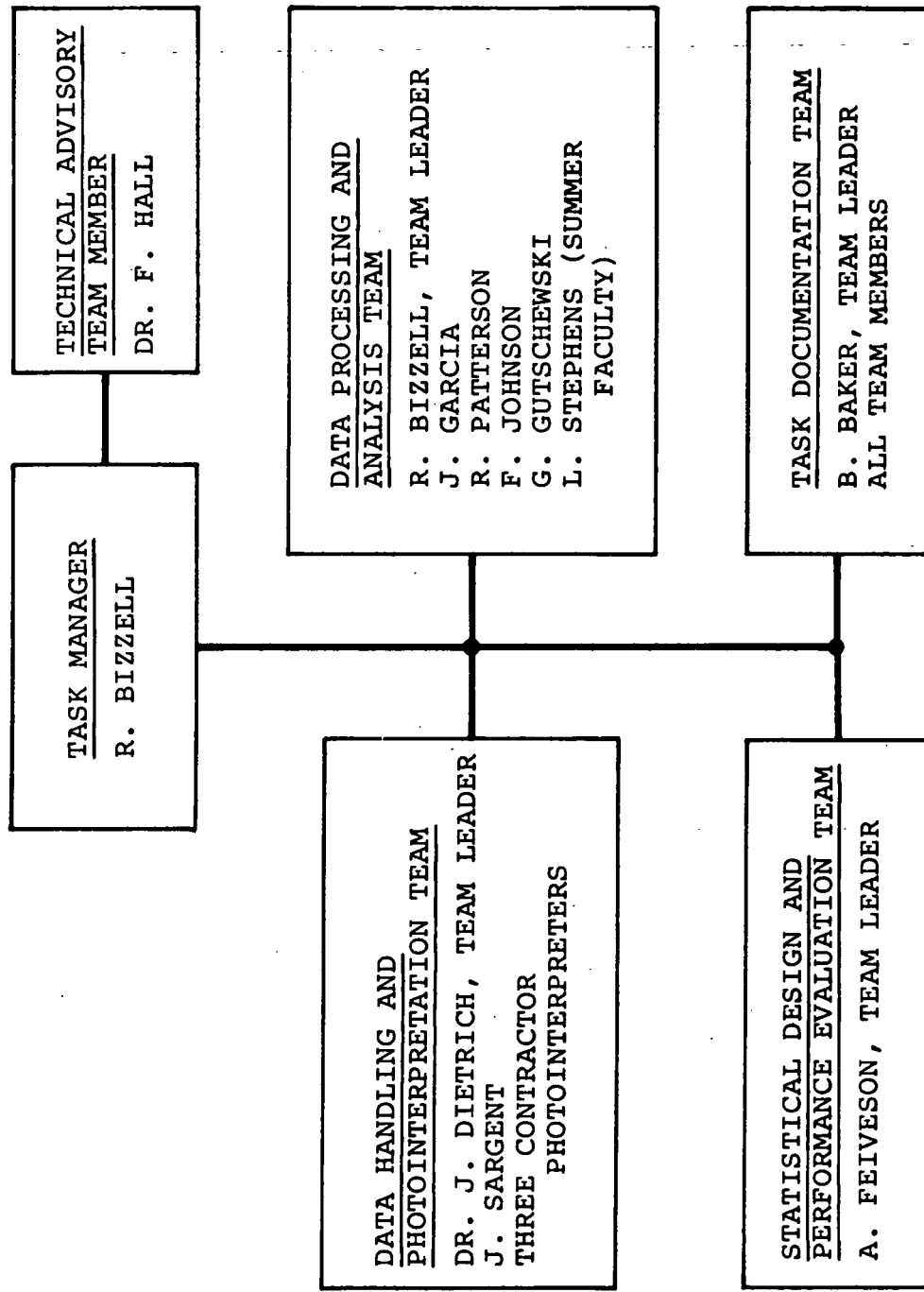


Figure 8.- Diagram of EOD key personnel assigned to the CITARS task.

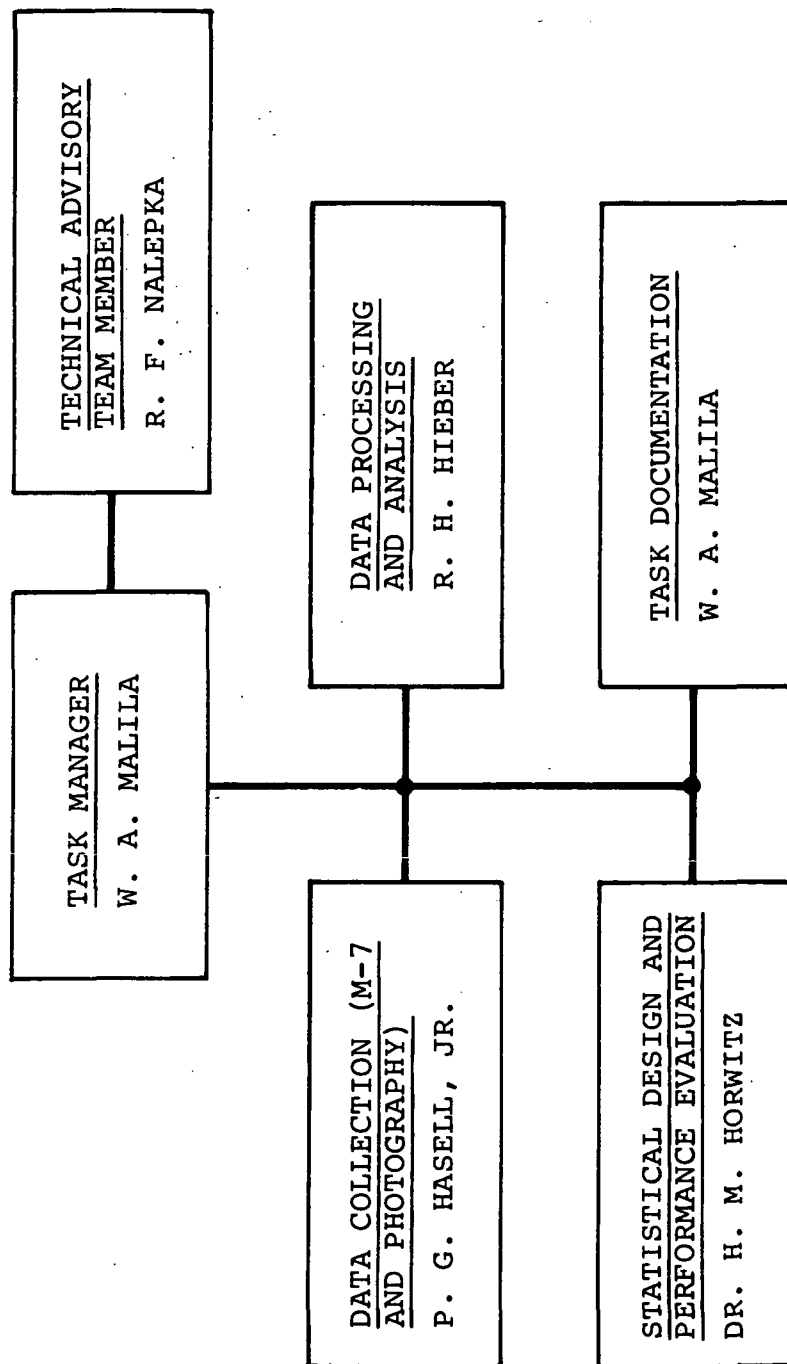


Figure 9.— Diagram of ERIM key personnel assigned to the CITARS task.

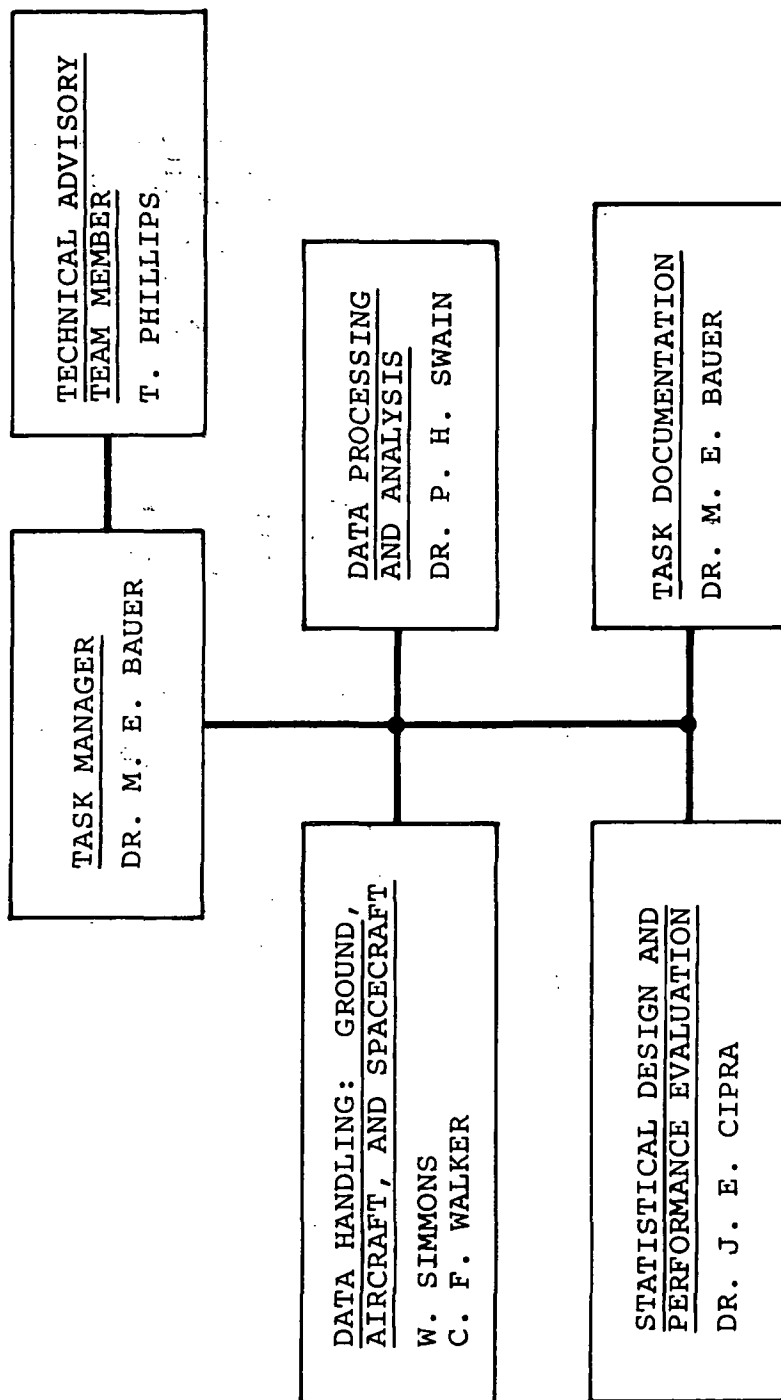


Figure 10.— Diagram of LARS key personnel assigned to the CITARS task.

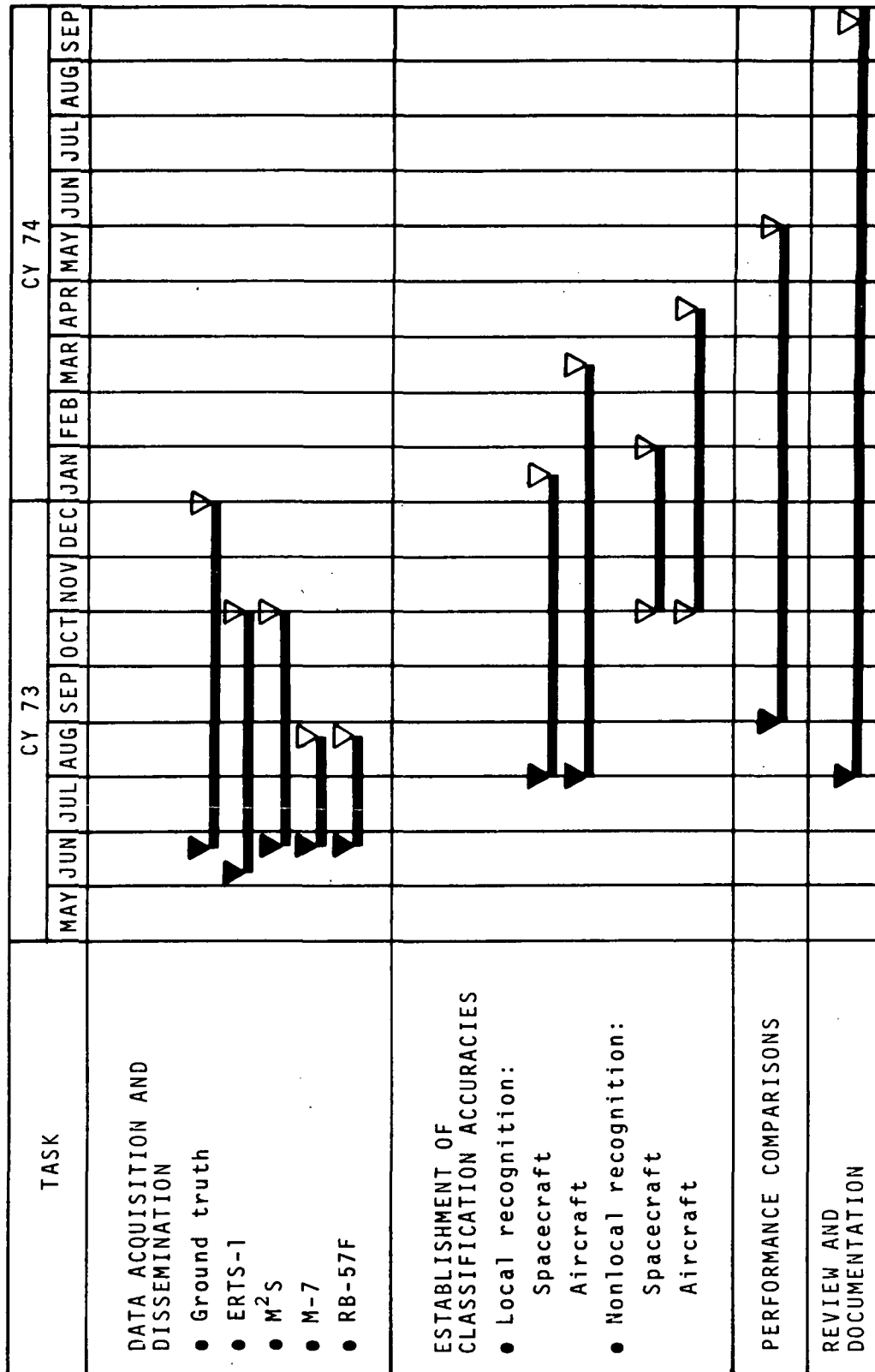


Figure 11.— Major task area milestones.

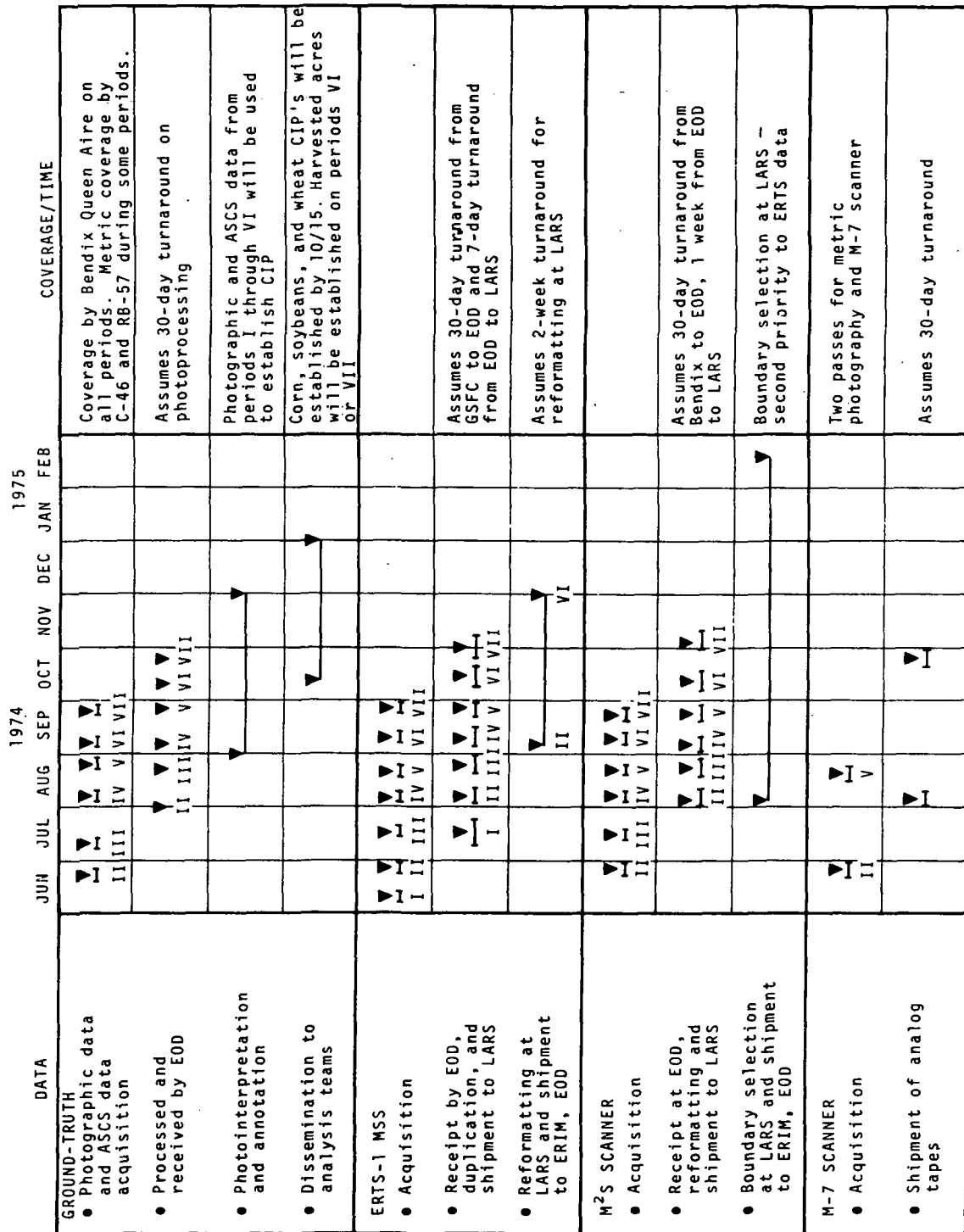
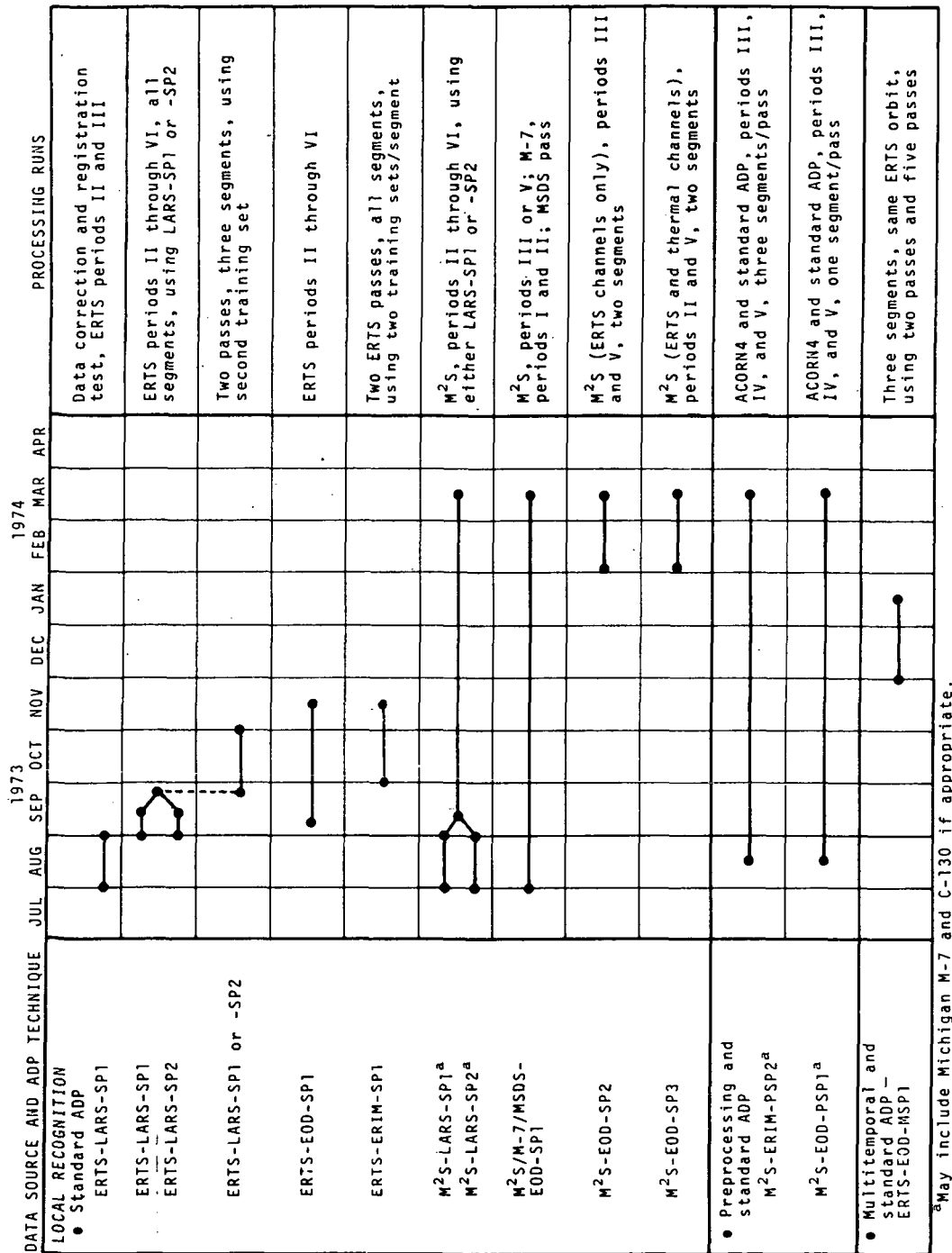


Figure 12.- Detailed data acquisition milestones.



^aMay include Michigan M-7 and C-130 if appropriate.

NOTE: These schedules assume 30-day turnaround on aircraft-spacecraft digital, photographic, and ASCS ground-truth data, allowing approximately 10 days for ADP analysis of all ERTS data (local training/local recognition) for one data acquisition period.

Figure 13.- Detailed data processing milestones.

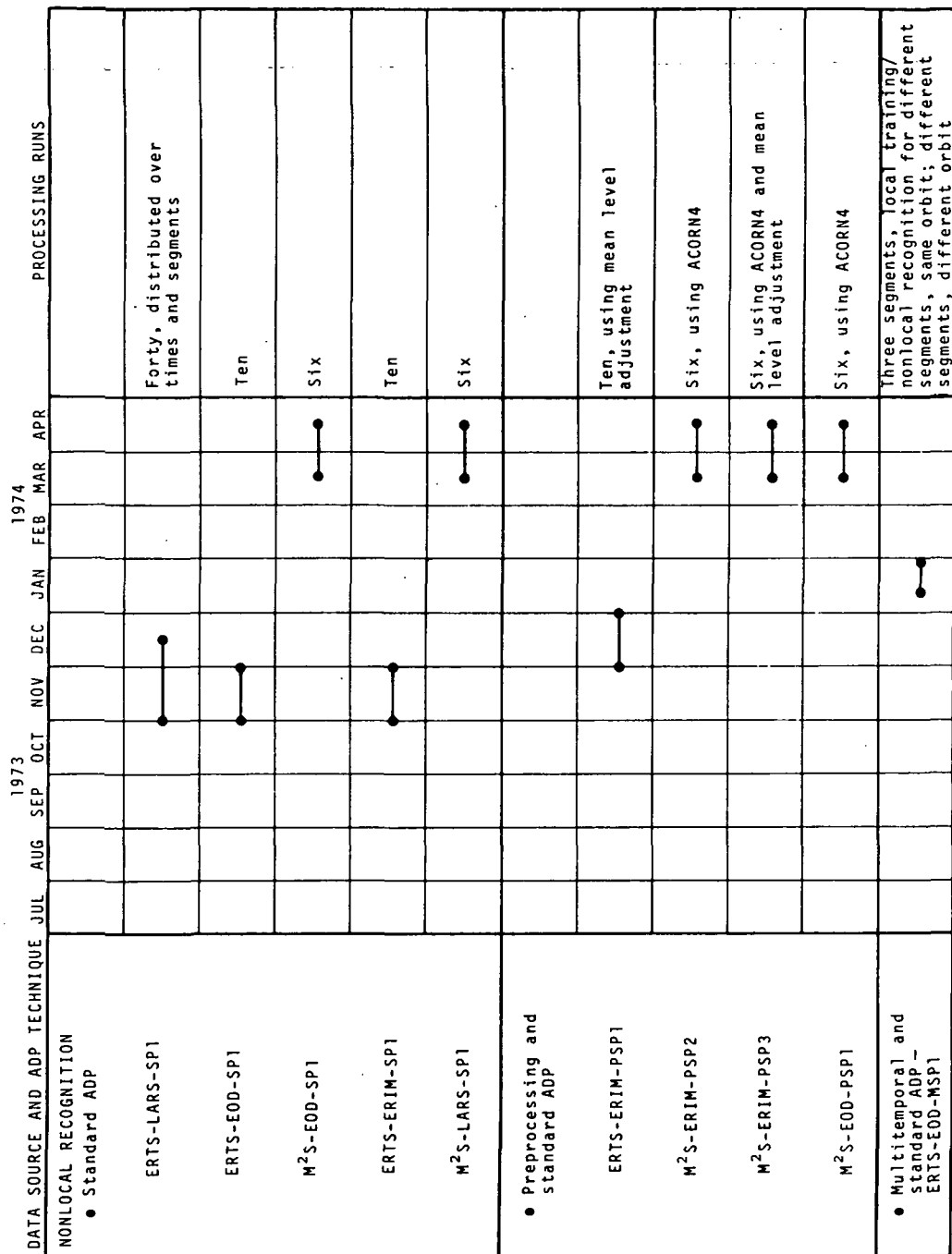


Figure 13.— Detailed data processing milestones (concluded).

| ANALYSIS TASK | | 1973 | | | | | 1974 | | | | | OBJECTIVE |
|---------------|--------------------------|------|-----|-----|-----|-----|------|-----|-----|-----|-----|--|
| NO. | DESCRIPTION | AUG | SEP | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | |
| I | ADP TECHNIQUES | | | | | ▼ | | | | | | To compare ERTS-ERIM-SP1, ERTS-LARS-SP1 and -SP2, and ERTS-EOD-SP1 for local training/nonlocal recognition |
| II | DATA ACQUISITION PERIODS | | | | | ▼ | | | | | | |
| III-A | PREPROCESSING | | | | | | ▼ | | | | | To compare performances during the growing season |
| III-B | PREPROCESSING | | | | | | | | | | | |
| IV-A | SIGNATURE EXTENSION | | | | | | | | | | ▼ | To ascertain the effect of preprocessing on aircraft data |
| IV-B | SIGNATURE EXTENSION | | | | | | ▼ | | | | | |
| IV-C | SIGNATURE EXTENSION | | | | | | | | | | | To compare ERTS-LARS-SP1 and -EOD-SP1 and -ERIM-SP1 for local training/nonlocal recognition |
| V-A | ERTS-AIRCRAFT | | | | | | ▼ | | | | | |
| V-B | ERTS-AIRCRAFT | | | | | | | | | | | To examine multiple aspects of signature extension |
| VI | ERTS-AIRCRAFT | | | | | | | | | | | |
| VII | MULTITEMPORAL | | | | | | | ▼ | | | | To compare ERTS and aircraft CIP with ERIM, LARS, and EOD |
| VIII | FIELD BOUNDARY | | | | | | | | | | | |
| IX | TRAINING SETS | | | | | ▼ | | | | | | To compare ERTS and aircraft data for all periods and segments |
| X | REGISTRATION | ▼ | | | | | | | | | | |
| XI | AIRCRAFT SCANNERS | | | | | | | | | | | To compare ERTS-aircraft (Δ ERTS channels), aircraft (all channels), and aircraft (ERTS-B) on CIP |
| XII | WHEAT | | | | | | | | | | | |
| | | | | | | | | | | | | To compare CIP on pure pixels to CIP on all pixels |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | To ascertain the effect of training field selection on CIP |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | To ascertain the effect of correction-registration on CIP |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | To compare performance with M ² S, M-7, and MSDS |
| | | | | | | | | | | | | |

Figure 14.— Performance comparison milestones.

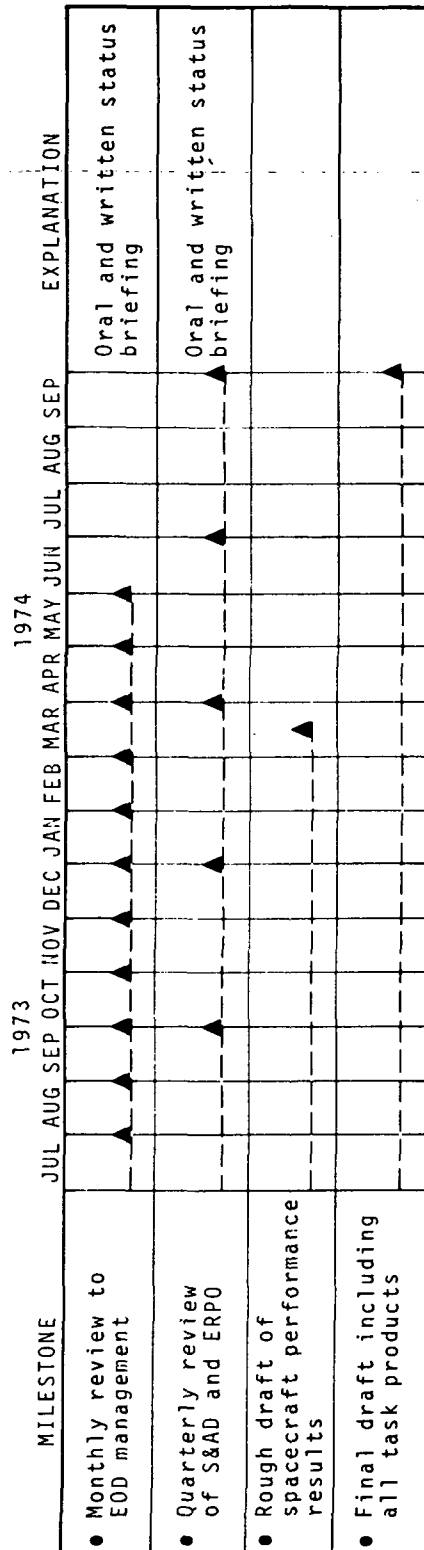


Figure 15.— Documentation milestones.

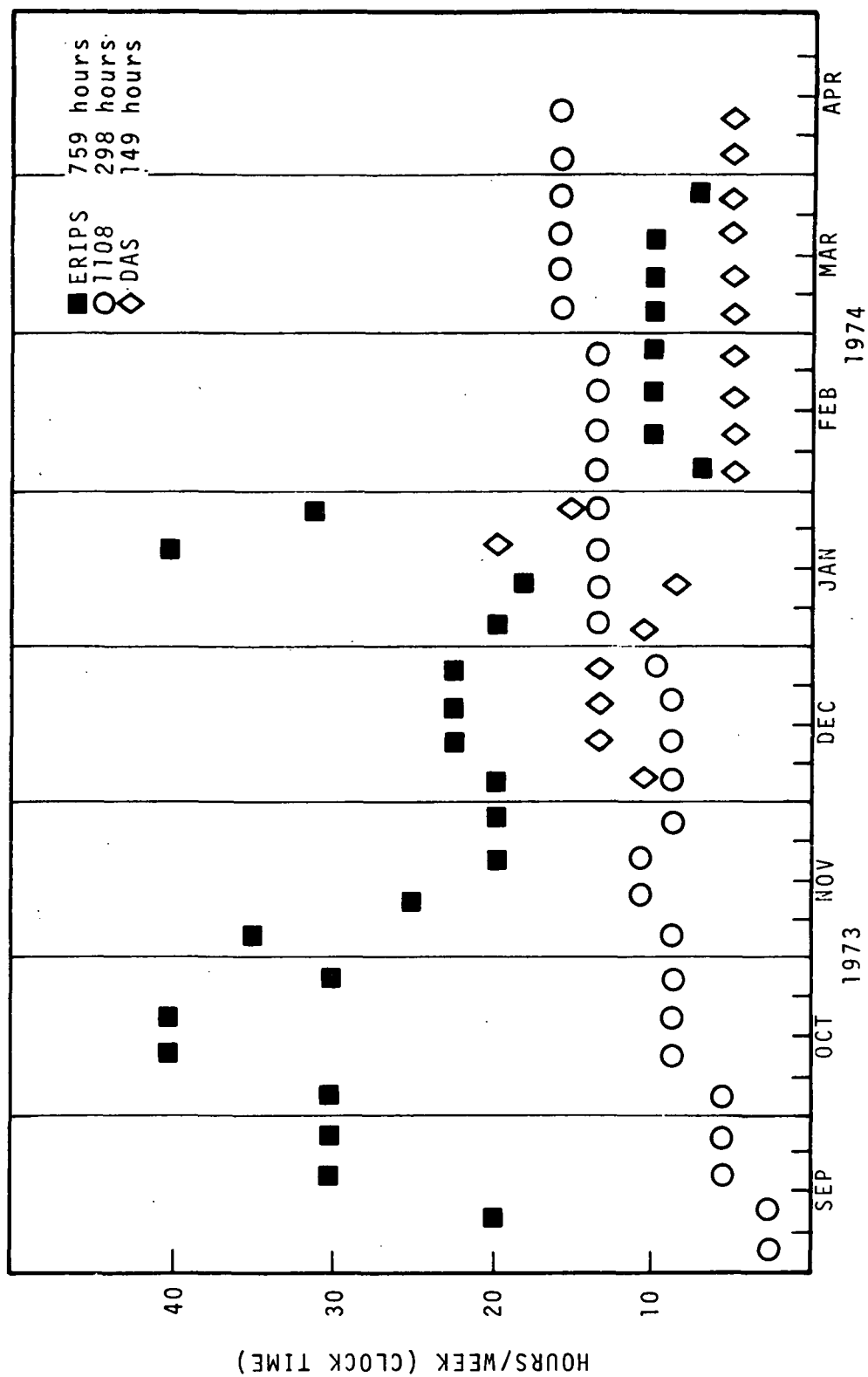


Figure 16.— Schedule of EOD data processing requirements on ERIPS, Univac 1108, and DAS.

APPENDIX A

PROCEDURES FOR SECTION AND QUARTER SECTION
SELECTION WITHIN SEGMENTS

APPENDIX APROCEDURES FOR SECTION AND QUARTER SECTION
SELECTION WITHIN SEGMENTS

A.1 SECTION AND QUARTER SECTION SELECTION

The following procedures will be used for selection of segments in each county and sections within each segment.

1. Obtain ASCS photoindex maps of each county.
2. To the scale of the photoindex maps, inscribe an 8- by 32-kilometer rectangle on a transparent overlay. To the same scale, inscribe five columns 1.6 kilometers wide and four rows 8 kilometers wide within the rectangle.
3. Assign a different integer to the northeast corner of each section on the photoindex map which is within the ERTS overlap. The northeast corner of each such agricultural section will be numbered.
4. From a sequence of random numbers, select the first member of the sequence. Let this number n designate a locus on the photoindex map corresponding to the northeast corner identified with the integer n from step 3. If no section locus corresponds to the number chosen from the table, repeat step 4 until a correspondence is found.
5. Place the transparent overlay developed in step 2 on the photoindex map and orient the rectangle roughly in a north-south position with respect to the index map. Align one corner of the rectangle so that it matches the locus identified in step 4 and so that the longest edge of the

rectangle, containing that corner, is coincident with the north-south agricultural section line containing the locus.

6. In case any part of this rectangle is not completely contained within the county or ERTS overlap area, repeat the procedure from step 4 until the rectangle is both within the county and the ERTS overlap area. The perpendicular distance from the predicted ERTS overlap ground track to either the northwest or southeast corner of the rectangle should not be less than 3.2 kilometers.
7. Within each row-column 1.6- by 8-kilometer element inscribed within the larger 8- by 32-kilometer rectangle, there should be five sections aligned north-south in a column. In case any of the row-column elements contain nonagricultural sections, such as urban structure, water bodies, forested areas, or pasture land, repeat steps 4 through 6 until each row-column element contains at least one section with at least one quarter section occupied by at least 90 percent agricultural fields. After a segment with these properties has been located, identify each section in each row-column element with a number from 1 through 5 so that no two sections within an element have the same number.
8. From a random number sequence from 1 through 5, select the first member of the sequence. Locate the corresponding agricultural section within the northwestmost row-column member of the large rectangle. If the section chosen in this manner is not an agricultural section, as defined in step 7, repeat step 8 until an agricultural section is chosen.

9. Repeat step 8, choosing the second, third, fourth, and fifth members of the random number sequence for each row-column element in the segment, until 20 agricultural sections are chosen, one in each row-column element.
10. Identify each quarter section within each section defined in step 9 with a number from 1 through 4 such that no two quarter sections have the same number.
11. For each section defined in step 9, select a quarter section from a random number sequence from 1 through 4. If the quarter section contains less than 90 percent agricultural fields, randomly select another quarter section. Continue selecting within each section until a quarter section containing at least 90 percent agricultural fields is selected. After ASCS photographs are obtained and the selection procedure is followed, the requirement will be relaxed to 80 percent because sometimes 90 percent cannot be obtained.
12. Designate each quarter section located by step 11 for field visitation.

A.2 TEST SECTION SELECTION

1. Number the sections within each segment from 1 through 100.
2. Using a random number table, select 20 sections within the segment such that no test section contains a quarter section to be visited by the ASCS.

APPENDIX B

PROCEDURES FOR TRAINING, PILOT, AND TEST FIELD SELECTION

APPENDIX B

PROCEDURES FOR TRAINING, PILOT, AND TEST FIELD SELECTION

B.1 TRAINING FIELDS

Crop fields from 10 of the ASCS' quarter sections will be used for training the classifiers. All fields large enough to be located accurately in the scanner imagery will be available for training. The 10 quarter sections will be selected at random from the 20 ASCS quarter sections.

Training areas for nonagricultural cover types not present in the 10 quarter sections will be selected arbitrarily from the base photography. These categories will be easy to identify on the photography. Typical examples are water bodies, forests, towns, and airports. If present in the segment, 10 areas of nonagricultural cover type will be selected and their coordinates located in the scanner imagery.

In order to compare results, all classifications will be performed using these training fields. No additional fields may be selected during the analysis. Fields may be deleted if not required by the particular analysis procedure being used.

B.2 PILOT AND TEST FIELDS

Fields from 10 sections will be used as pilot fields, and the fields from 10 other sections will be used as test fields. Pilot and test fields are described in section 3.0.

The crop identification data for these 20 sections will be obtained by photointerpretation of multitemporal color infrared photography.

The 20 sections are to be random selections from 80 sections in the segment. The 20 sections from which the ASCS quarter sections were selected are to be excluded.

Because the total number of sections with ground truth will be divided between pilot and test sections, the first 10 sections selected are recommended for use as pilot fields and the second 10 for test fields. The assignment of the sections as pilot or test fields should then be reversed. This will give two independent measures of the CIP for each segment.

APPENDIX C

PROCEDURES FOR LOCATION OF FIELD BOUNDARIES

APPENDIX C

PROCEDURES FOR LOCATION OF FIELD BOUNDARIES

The boundaries of training, pilot, and test fields and pilot and test sections will be located by LARS personnel. The location will ensure that all analysts use the same boundaries and will reduce duplication of effort.

Several methods were evaluated to determine the best way to locate boundaries accurately and easily. For ERTS data, the methods include using single-band gray-scale maps, nonsupervised classification maps, and maps of the first and second principal components. In many cases, single-band gray-scale maps were satisfactory for accurately locating fields. These maps are also the easiest to obtain. In cases of minimal contrast among fields, nonsupervised classifications resulted in enhanced images. Use of principal components did not result in improved images when compared to either of the other methods.

Geometrically deskewed and rescaled ERTS data were found to be much easier to use than the unprocessed data. For aircraft scanner data, the video digital display screen was found to be useful for this task. However, on ERTS data, fields are too small to enclose with boundaries.

The standard way to locate fields in ERTS data will be to use gray-scale line printer maps of geometrically corrected data. The digital display unit will be used to locate boundaries in the aircraft data. The following steps will be taken.

C.1 GENERATE GRAY-SCALE MAPS

An alphanumeric pictorial printout will be produced using the PICTUREPRINT function for each of the four ERTS bands. Experience indicates that 10 gray levels show the contrast between fields most accurately. Predefined symbols programmed into PICTUREPRINT will be used. The data for each channel will be histogrammed, and printer symbols will be assigned to gray levels so that each symbol has an equal probability. The histograms will be computed for the entire segment. An appropriate input deck for PICTUREPRINT is:

```
PICTUREPRINT  
DISPLAY RUN (XXXXXXXX) LINE (A,B,C), COL (X,Y,Z)  
CHANNELS 1,2,3,4  
PRINT HIST  
END
```

C.2 OUTLINE HIGHWAYS AND LANDMARKS

Roads and other significant landmarks in the segment, such as towns and lakes, will be located, drawn in, and labeled on the gray-scale map. Generally, band 2 (0.60 to 0.70 micrometers) proved to be best and will be used. In this step, most of the sections will be outlined in the data because many sections have perimeter roads. As part of this step, exact segment boundaries will be located and drawn on the gray-scale maps.

C.3 LOCATE GROUND-TRUTH SECTIONS

Each section or quarter section with training, pilot, or test fields will be located; and the coordinates of the

section or quarter sections will be obtained. Band 2 (0.60 to 0.70 micrometers) will be used to locate sections with ground truth. Using blue pencil, the perimeter of the sections and quarter sections will be outlined and the identifications written. Coordinates will be recorded on field coordinate sheets for later keypunching.

The gray-scale map of band 4 will be overlaid on the map of band 2 on the light table. The roads on the band 2 map will be transferred to the band 4 map.

C.4 LOCATE FIELD BOUNDARIES

The field boundaries will be drawn in red pencil on the gray-scale map of band 4 (0.8 to 1.1 micrometers). Field numbers will be marked in red pencil within the field. If the field is too small, the numbers will be marked in red pencil outside with an arrow pointing to the field.

When boundaries between fields are not obvious, measurements taken from the base map photography will be used to locate boundaries in the ERTS data. Because the base map and ERTS imagery will not be the same scale, the measurements will be on the basis of proportions of distance between identifiable points.

If the ERTS imagery is unsuitable for readily identifying field boundaries because contrast between fields is low, clustering will be used to enhance the image. The 20 ASCS quarter sections will be clustered using function CLUSTER. Eight classes will be requested, statistics for these classes will be punched, and the entire segment will be classified to produce a new gray-scale map.

An appropriate input deck for CLUSTER would be:

```
CLUSTER
CHANNELS 1,2,3,4
OPTIONS MAXCLAS (8), CONV (99.0)
PUNCH STATS
ID NUMBER 999
DATA (field coordinate cards)
END
```

After obtaining the punched statistics from CLUSTER, the functions CLASSIFYPOINTS and PRINTRESULTS will be run to obtain the new map. An appropriate control deck would be:

```
CLASSIFYPOINTS
CHANNELS 1,2,3,4
RESULTS DISK
DATA
RUN (XXXXXXXX), LINES (A,B,C), COL (X,Y,Z)
END
PRINTRESULTS
RESULTS DISK
SYMBOLS M,$,X,I,/,-,...,
END
```

After obtaining the map from these steps, the fields would be located as described previously.

C.5 DEFINE FIELD CENTERS

To delineate the field centers within the field boundaries, the two general classes of boundary situations will be handled in these ways:

1. Where a line (column) of boundary elements dissimilar to the adjacent field elements exists, the first lines on each side of the boundary are selected as the first lines of the fields. See figure C-1.
2. If no boundary elements appear between two fields where the ground truth shows a boundary, the first line in each field will be considered contaminated. The second line will be used as the field boundary line. See figure C-2.

These methods were adopted to avoid including edge effects in the field centers.

C.6 OBTAIN SECTION AND FIELD CARDS

The field center coordinates will be transferred to field description coding sheets (fig. C-3.) Each field must be uniquely identified by segment, section, and field number in columns 11 through 18. The field crop identity, such as corn, soybeans, wheat, or pasture, will be punched in columns 51 through 58. The use made of the field, such as training, pilot, or test, will be in columns 59 through 72. Coding sheets will be keypunched and verified by experienced keypunch operators.

C.7 DISPLAY AND CHECK BOUNDARIES

After the field coordinate cards have been punched and returned, PICTUREPRINT will be used to display the boundaries defined. Two passes with PICTUREPRINT will be needed. The first pass will show the test section and training quarter section boundaries. The second pass will show the training and test field center boundaries. All boundaries will be examined to ensure that they were located accurately and any changes or corrections needed will be made. An example of the appropriate control deck is:

```
PICTUREPRINT
BOUNDARY OUTLINE, STORE
DISPLAY RUN (XXXXXXXX), LINE (A,B,C), COL (X,Y,Z)
HISTOGRAM DISK
CHANNELS 2
CLASS (training field coordinate cards)
TEST (test field coordinate cards)
END
```

C.8 EDIT FOR SUBSEQUENT MISSIONS

Since data from later ERTS passes will be registered to the first data, field boundaries will not be relocated except for actual boundary changes. An example of a change is a wheatfield partially plowed after harvest, which would later be considered two fields.

Fields in which the crop or use changed between missions will be noted. Data for fields covered by clouds or cloud shadows will be deleted on each mission.

C.9 PREPARE DECKS

A deck of section and field boundaries will be prepared for each mission date. For each analysis, five distinct decks will be supplied: available training fields, pilot fields, test fields, pilot sections, and test sections. The decks will be supplied in the order specified and labeled clearly. Each deck containing field boundaries should be organized as follows:

TEST 1 (cornfield cards)

TEST 2 (soybean field cards)

TEST 3 (wheatfield cards if wheat is to be discriminated.

Otherwise, the other cards should be headed by

TEST 3)

TEST 4 (other field cards)

Each deck containing section boundaries should be organized as follows:

TEST 1 (section boundary cards)

The order of decks and classes must be observed so that the tabulations of results will be organized properly.

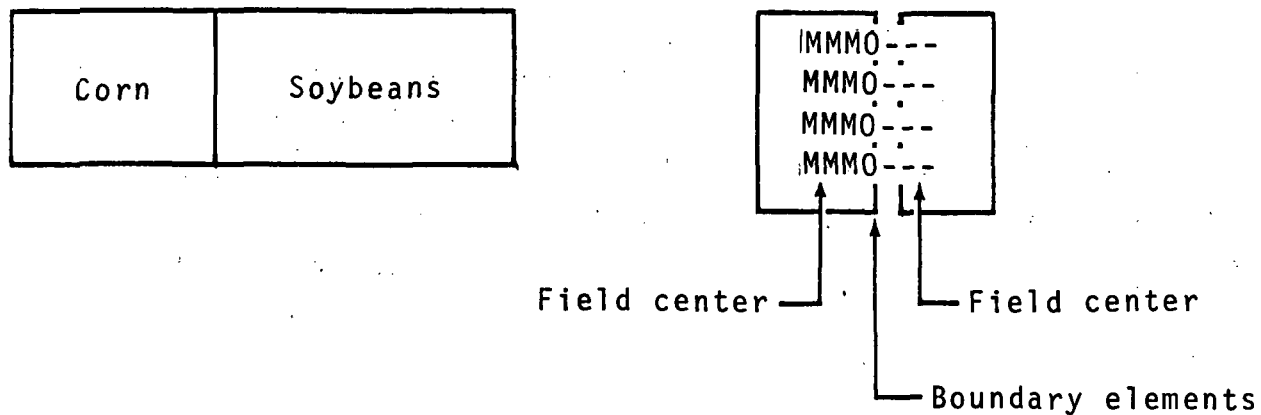


Figure C-1.— Diagram showing existence of boundary elements between fields where not indicated by ground truth.

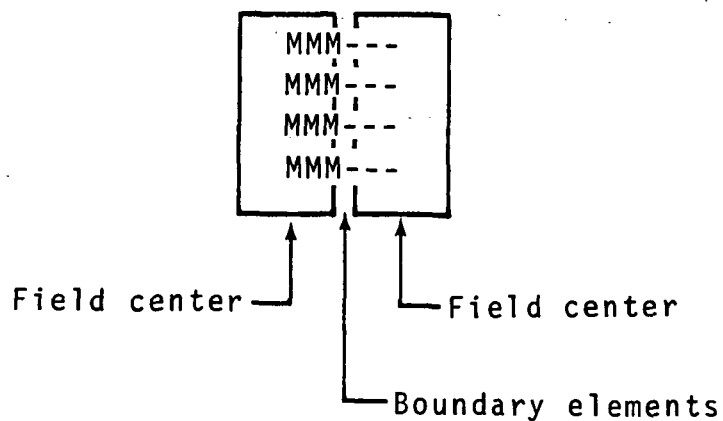


Figure C-2.— Diagram indicating no boundary elements where a boundary has been indicated by ground truth.

[illegible]

Figure C-3.— Example of field description coding sheets.

APPENDIX D

TEST SEGMENT SECTION LOCATIONS FOR
TEST AND PILOT FIELDS

APPENDIX D

TEST SEGMENT SECTION LOCATIONS FOR
TEST AND PILOT FIELDS

Figures D-1 through D-6 are idealized sketches of the six CITARS test area segments.

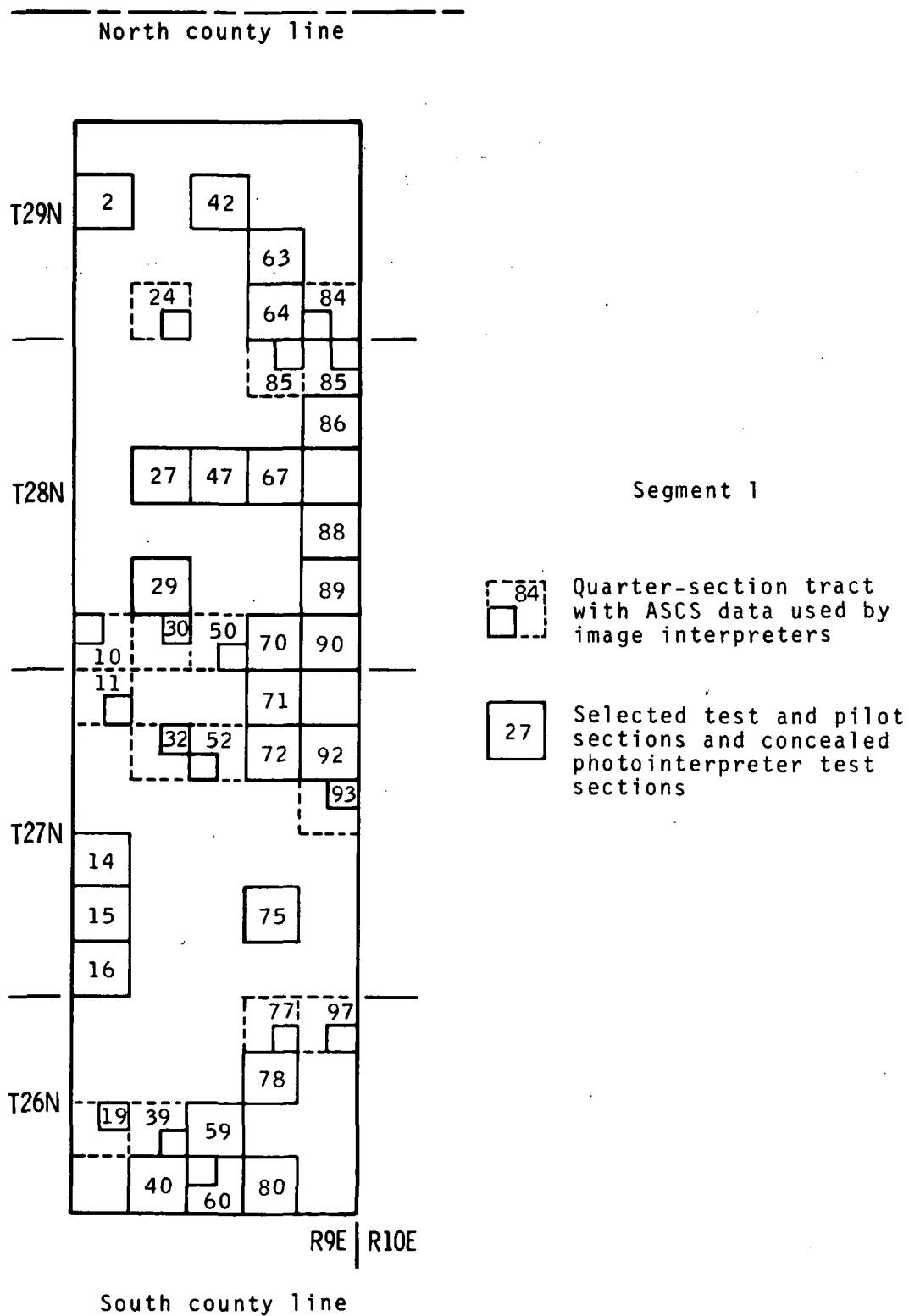


Figure D-1.— Idealized sketch of Huntington County test segment.

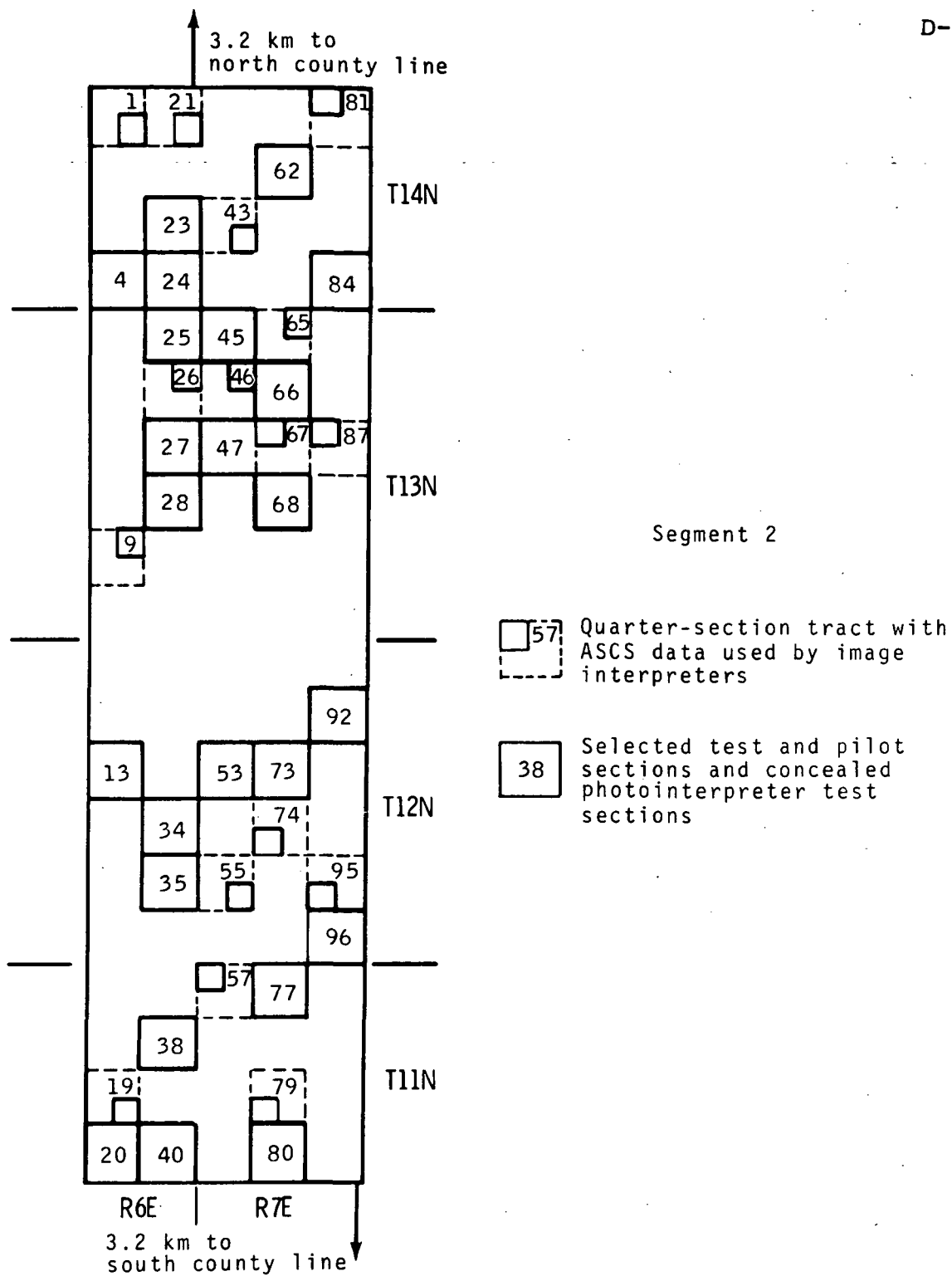


Figure D-2.— Idealized sketch of Shelby County test segment.

D-4

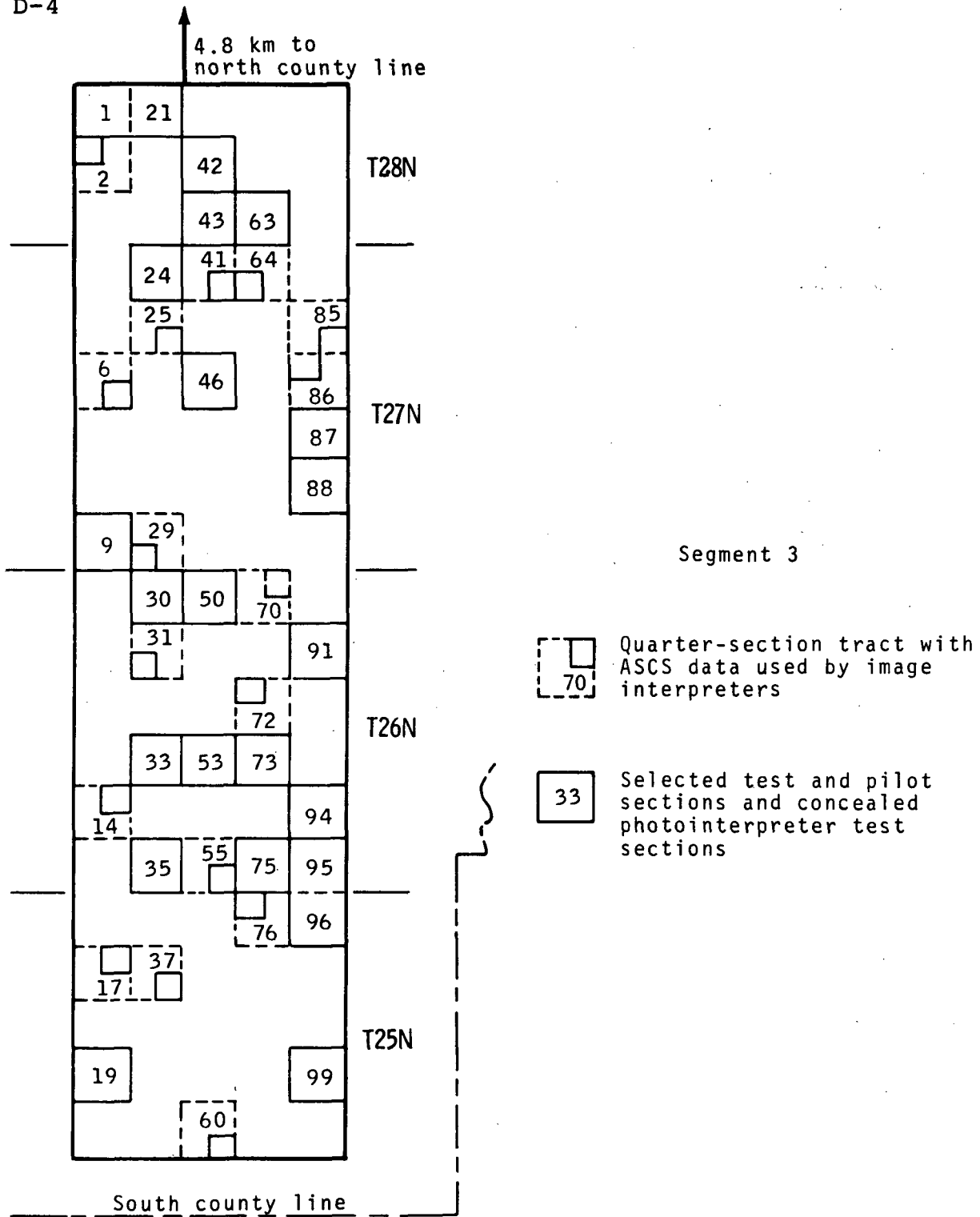


Figure D-3.— Idealized sketch of White County test segment.

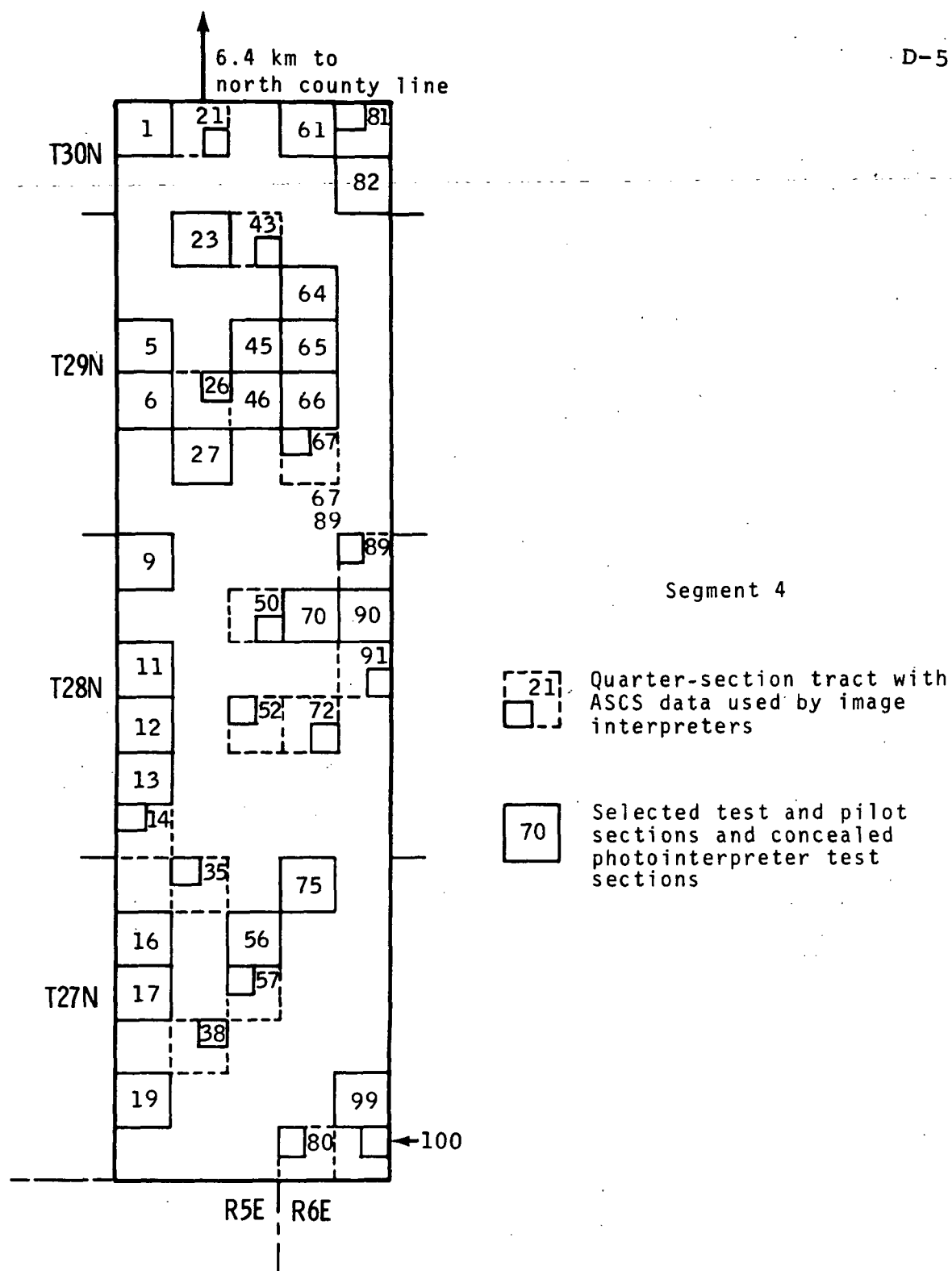


Figure D-4.— Idealized sketch of Livingston County test segment.

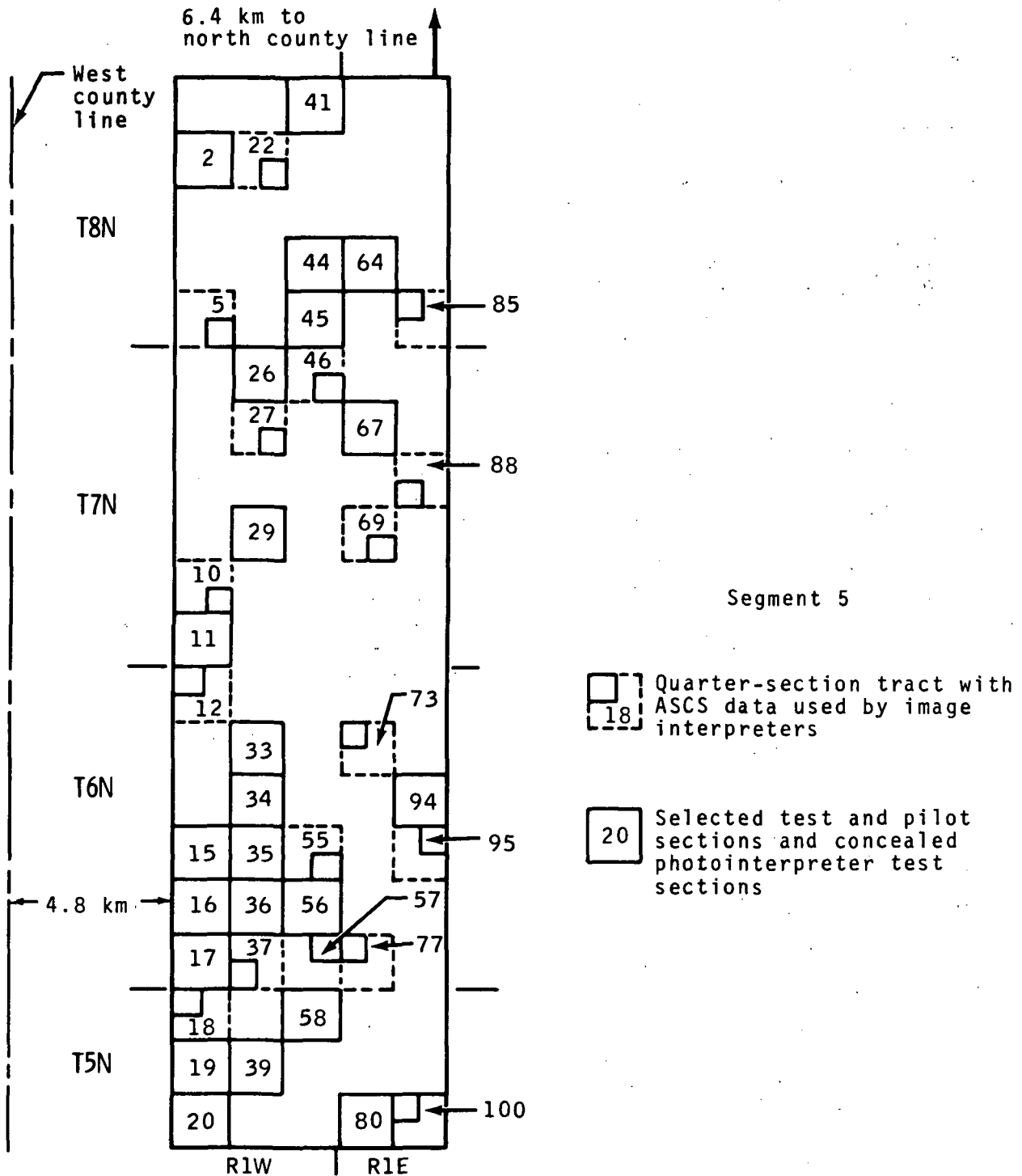


Figure D-5.— Idealized sketch of Fayette County test segment.

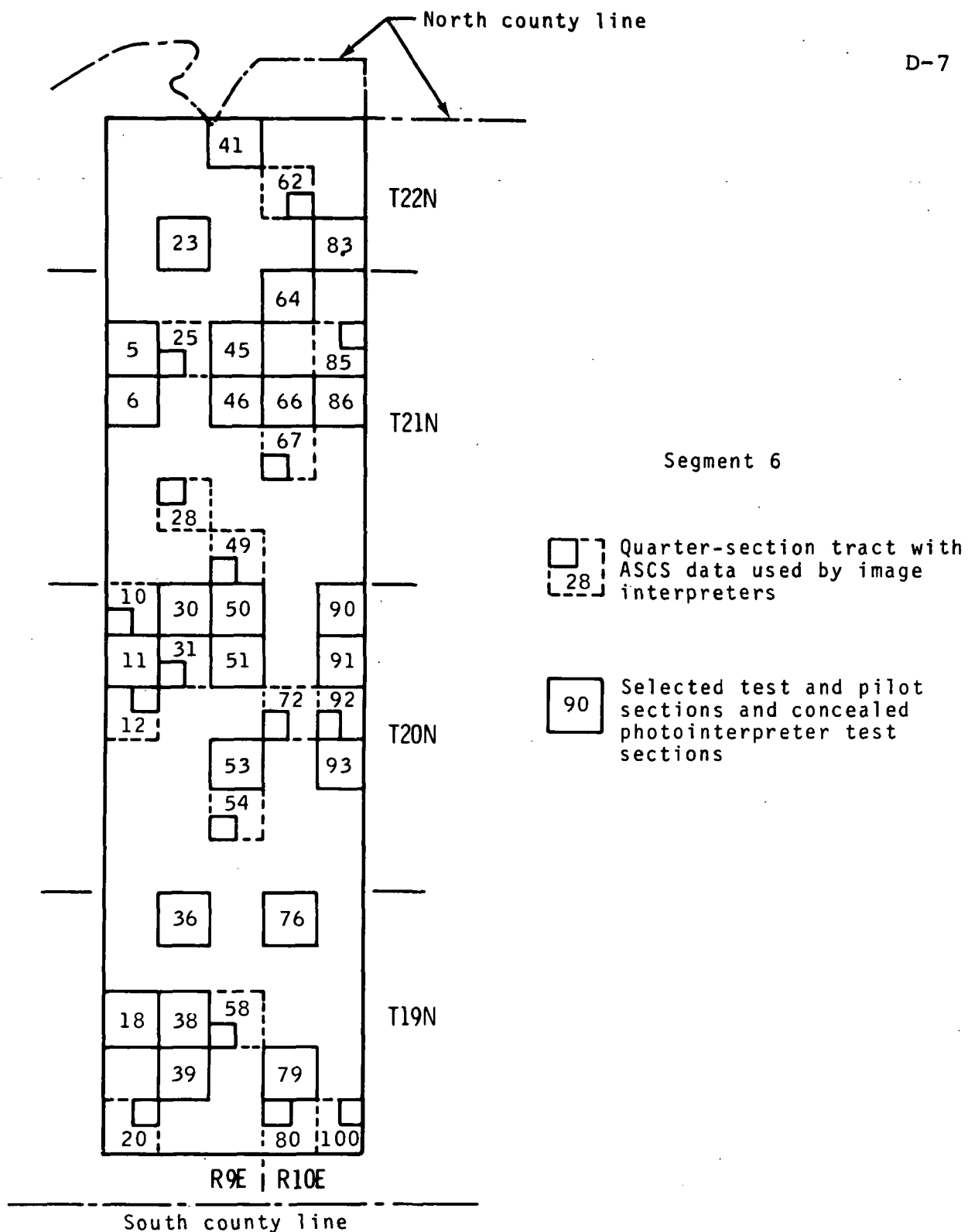


Figure D-6.— Idealized sketch of Lee County test segment.

APPENDIX E
PHOTOINTERPRETIVE PROCEDURES

APPENDIX EPHOTOINTERPRETIVE PROCEDURES

E.1 IMAGE INTERPRETATION PLAN

After the Image Interpretation Team receives suitable aircraft photographs, data reduction will begin, using existing equipment within the Image Analysis Section. Each of the three interpreters will be assigned primary responsibility for two segments.

All data received by the team will become part of a data retrieval system. The retrieval system will facilitate the acquisition of records, comparisons, and summaries from a single source covering all materials accumulated during the image interpretation. This file of imagery, ground truth, crop identification summaries, and other materials will be kept current.

Duplicate transparencies of the color infrared film will be screened, as received, for geographic location and percentage of cloud cover before beginning the crop identification analysis. The Image Evaluation Team does not plan to screen completely or index the film.

After determining the extent of photographic coverage, the quarter sections investigated by ASCS personnel and the sections used in the crop identification extension through image interpretation will be identified.

All fields within these sections will be delineated and assigned identification numbers. The fields in quarter sections, which will be used by the Image Evaluation Team for training and establishment of crop signatures, will be identified by numbers assigned by the ASCS teams. The numbers will be permanent identification of each field throughout the experiment.

Ground-truth fields for each crop category will be examined to establish characteristic spectral signature responses as recorded on the color infrared aerial film.

The color, hue, texture, field, and row patterns will be noted for corn, soybeans, and wheat on each set of imagery analyzed.

Basic image interpretation procedures, including the use of suitable illumination, magnification, and stereoscopic equipment, will be used. Data recorded by ASCS personnel on the ground observation sheets will be compared with field signature responses.

Crop identification keys will be developed for extending the identification to fields in areas adjoining the quarter-section tracts investigated by the ASCS teams. Temporal keys will be developed as successive sets of imagery are acquired.

Each field delineated for interpretation and assigned a number will undergo conventional image interpretation.

The signature of each field will be compared with the crop identification keys developed from ground investigation data. At the earliest feasible date, a tentative identification together with a confidence level of high, medium, or low will be recorded for each field.

As additional imagery is acquired, the temporal history of each test field will be evaluated and compared with the temporal keys developed through the study of imagery covering fields visited by the ASCS.

Crop identifications will be refined as changes are detected through image analysis. The tentative identifications and confidence levels will be compiled throughout the growing season with comments concerning row direction and width, field vigor, and other factors.

Within 2 weeks after receipt of imagery from the September 1973 aircraft mission, a final crop identification will be assigned to each field.

Fields appearing atypical or areas with special or unusual characteristics within a field will be documented properly.

After completing the crop identification extension, the Image Interpretation Team will determine the proportions of corn, soybeans, wheat, and "other" in each section in the crop identification analysis. In computing the proportions, the area occupied by each crop will be measured precisely on metric imagery.

E.2 REPORTS

The initial report will consist of an annotated photobase and tabular identification summary covering each tract investigated by the ASCS teams. See figures E-1 and E-2. The reports covering tracts used to test the accuracy of the crop identification extension will be concealed from the Image Analysis Team. The initial report will be submitted 4 weeks after receipt of the first set of usable aircraft imagery. All fields in the sections used for image analysis will be delineated and identified by number.

An interim report will be made, giving the current tabular identification summary and, if changes have been made, the annotated photobase. This report will be issued as required by the ADP teams. See figures E-3 and E-4.

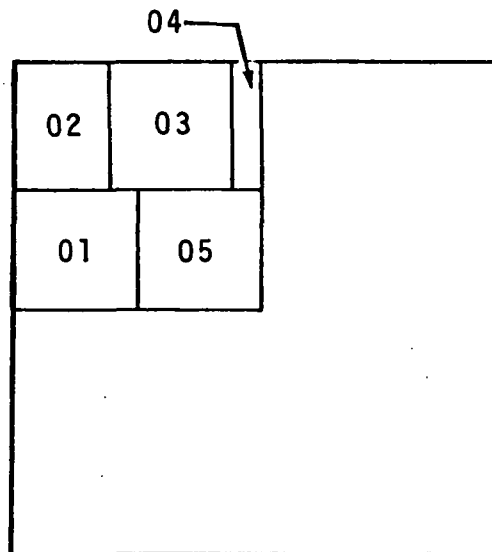
The final crop identification report will consist of copies of the crop identification summary sheet for each section involved in the analysis. The report will be submitted within 2 weeks after receipt of the imagery from the last aircraft mission.

A crop proportion report (table E-I) will be prepared by January 1, 1974. The report will consist of an annotated base photograph, the tabular crop identification summary for each section in the crop identification analysis, and the proportions of corn, soybeans, wheat, and other substances calculated from precisely measured crop areas.

A final report will be submitted by April 1, 1974. It will include summaries of the final crop identification and crop proportion reports and complete documentation of all interpretation and other tasks performed.

TABLE E-I.— EXAMPLE OF A CROP PROPORTION REPORT FOR
FAYETTE COUNTY

| Section | Calculated proportion (1% of section) | | | | | | |
|---------|---------------------------------------|----------|-------|-------|-------|-------|-------|
| | Corn | Soybeans | Wheat | Water | Trees | Urban | Other |
| 2 | 33.5 | 29.7 | 5.0 | 1.0 | 15.1 | 10.1 | 6.6 |
| 11 | 50.0 | 25.0 | 0.0 | 0.0 | 17.3 | 0.0 | 7.7 |
| 15 | 45.3 | 40.9 | 3.1 | 5.6 | 3.0 | 0.0 | 2.1 |
| 16 | 0.0 | 0.0 | 0.0 | 0.0 | 5.0 | 87.0 | 8.0 |
| 17 | 18.7 | 12.0 | 0.0 | 3.3 | 61.5 | 0.0 | 5.5 |



NOTE: A base photograph is projected within the overall area of this square.

Figure E-2.— Example of annotated photobase to be included with initial report for section 15 in Livingston County, Illinois.

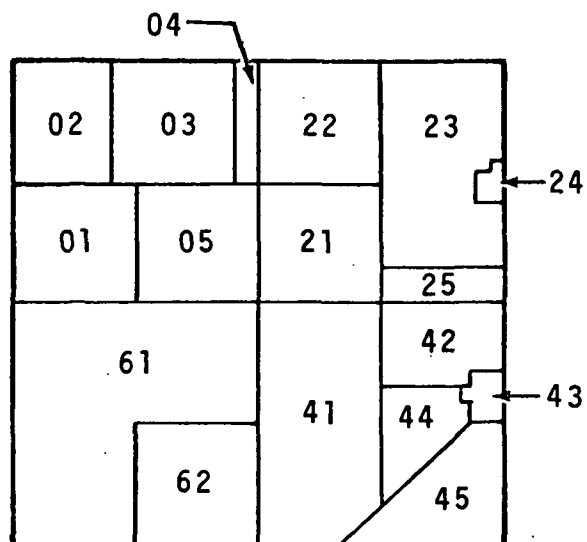
E-8

County LIVINGSTON Township 28N Range 6E Section 15

[illegible]

1158-1162

Figure E-3.- Example of interim or final report for section 15 in Livingston County, Illinois.



NOTE: A base photograph is projected within the overall area of this square.

Figure E-4.— Example of annotated photobase to be included with interim report for section 15 in Livingston County, Illinois.

APPENDIX F

PROCEDURES FOR TESTING ACCURACY OF PHOTOINTERPRETATION

APPENDIX FPROCEDURES FOR TESTING ACCURACY OF PHOTOINTERPRETATION

For each of six segments there are sections containing one ground-truth quarter section. Three or four of these sections, depending on field sizes, were selected as test areas. For each test area, the photointerpreters will classify the fields without knowledge of any ground truth within the section. One of the quarter sections in each test area has been ground-truthed and will be checked against the photointerpreters' results. The photointerpreters will not know which of the quarter sections were ground-truthed.

In addition, the photointerpreters will also classify dummy sections, totaling eight sections per segment. The photointerpreters will not know which of the eight sections actually contain a ground-truthed quarter section. The dummy sections were chosen as part of the 7.74-megameter² area so that manpower expenditure in classifying them will not have been wasted.

If any discrepancies arise, it may be necessary to redefine the photointerpretive classification procedures and to test further.

Figures F-1 through F-6 show the locations of the eight sections per segment that the photointerpreters will classify. The annotations on the edges of each segment are township and range designations. The dotted horizontal lines are drawn at 8-kilometer intervals, beginning at the top of each segment.

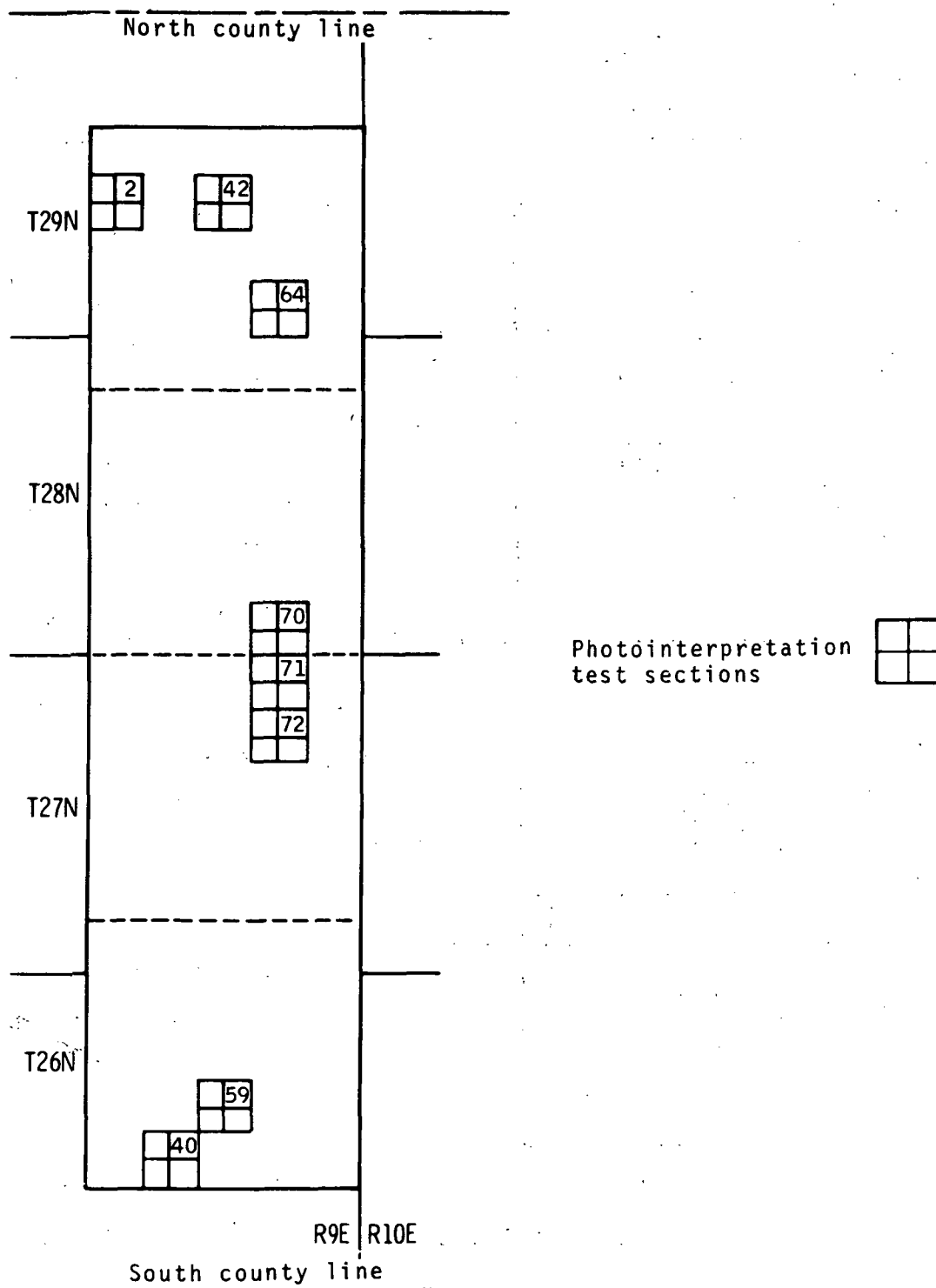


Figure F-1.- Idealized sketch of Huntington County ground investigation tracts.

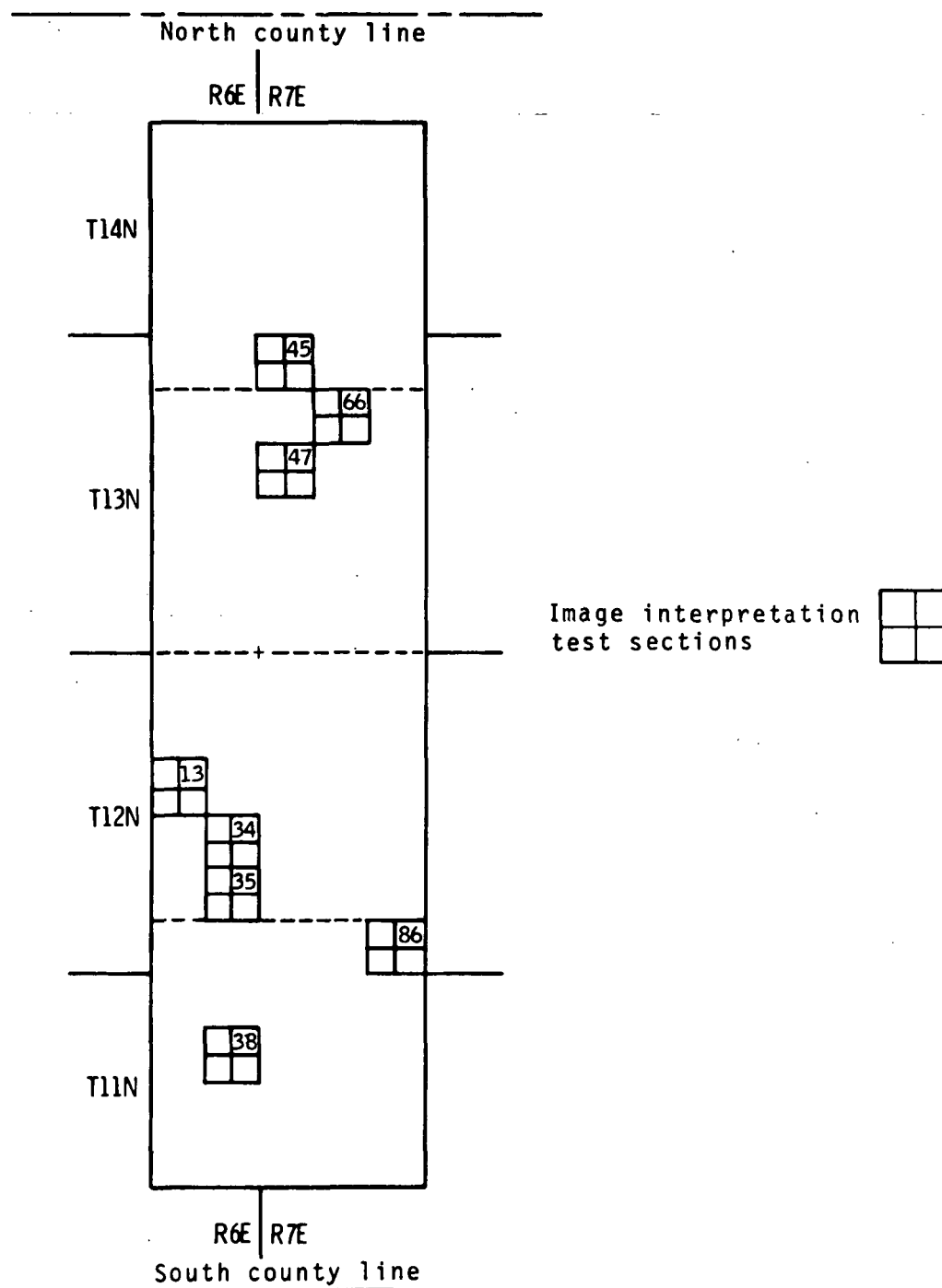


Figure F-2.— Idealized sketch of Shelby County ground investigation tracts.

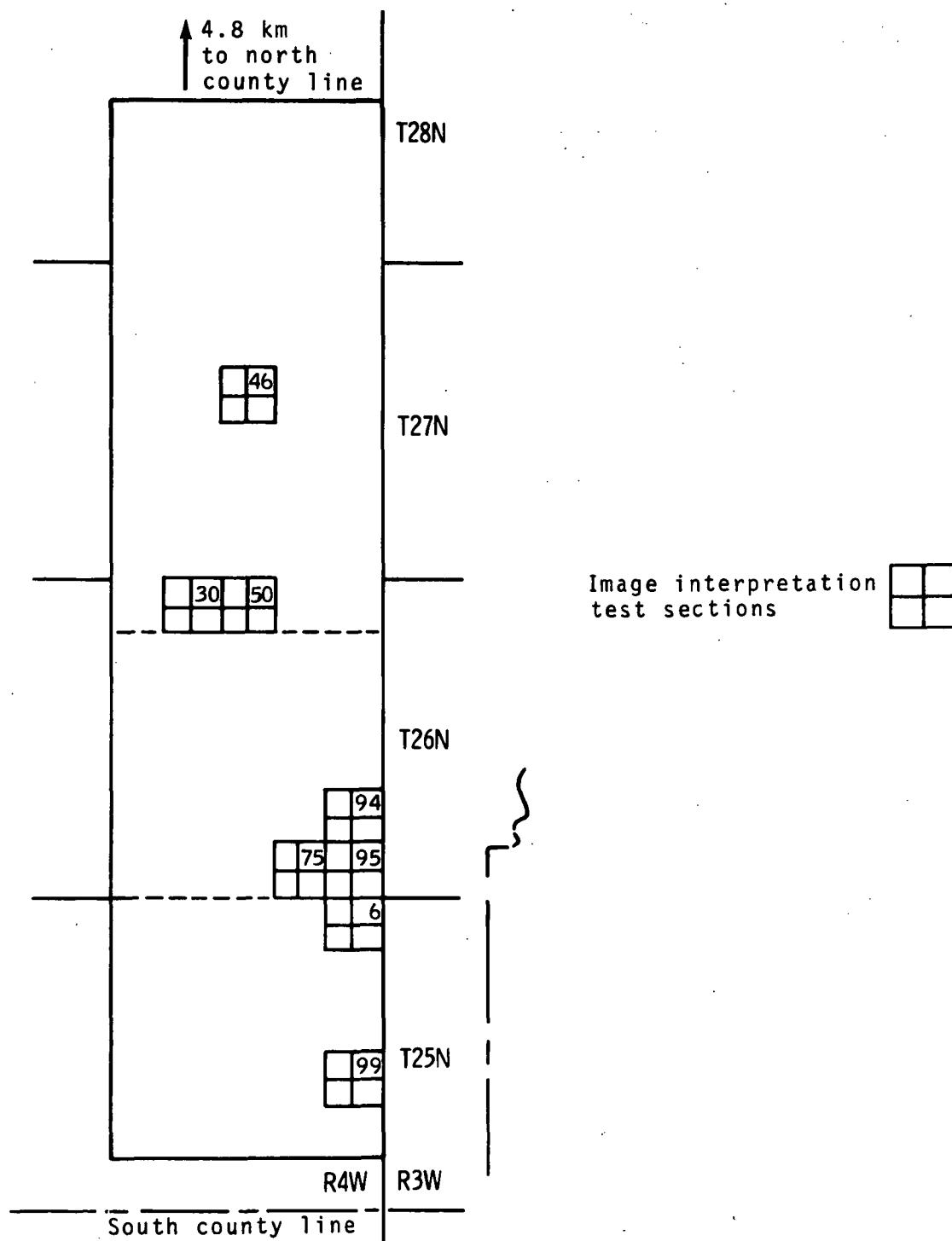


Figure F-3.— Idealized sketch of White County
ground investigation tracts.

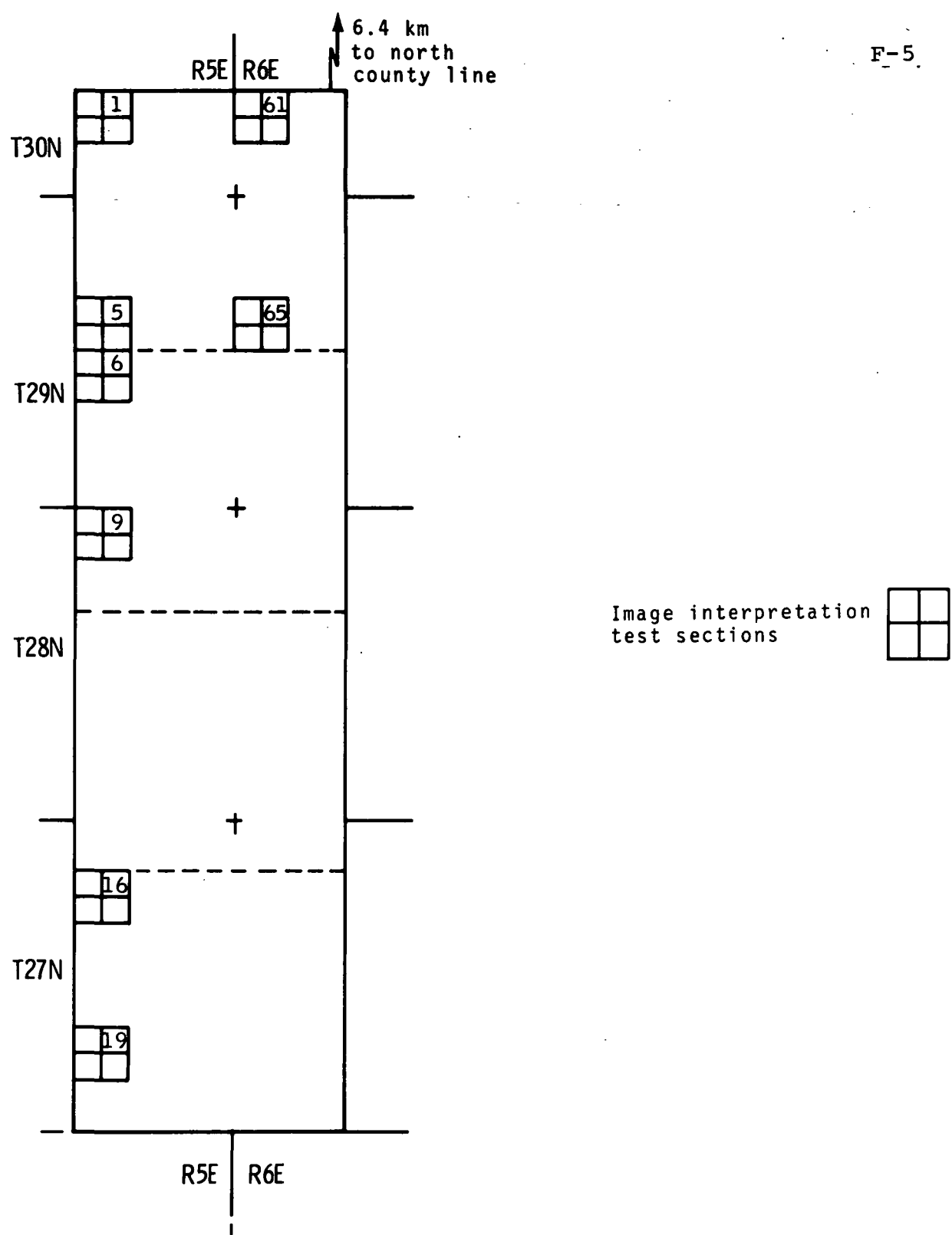


Figure F-4.- Idealized sketch of Livingston County ground investigation tracts.

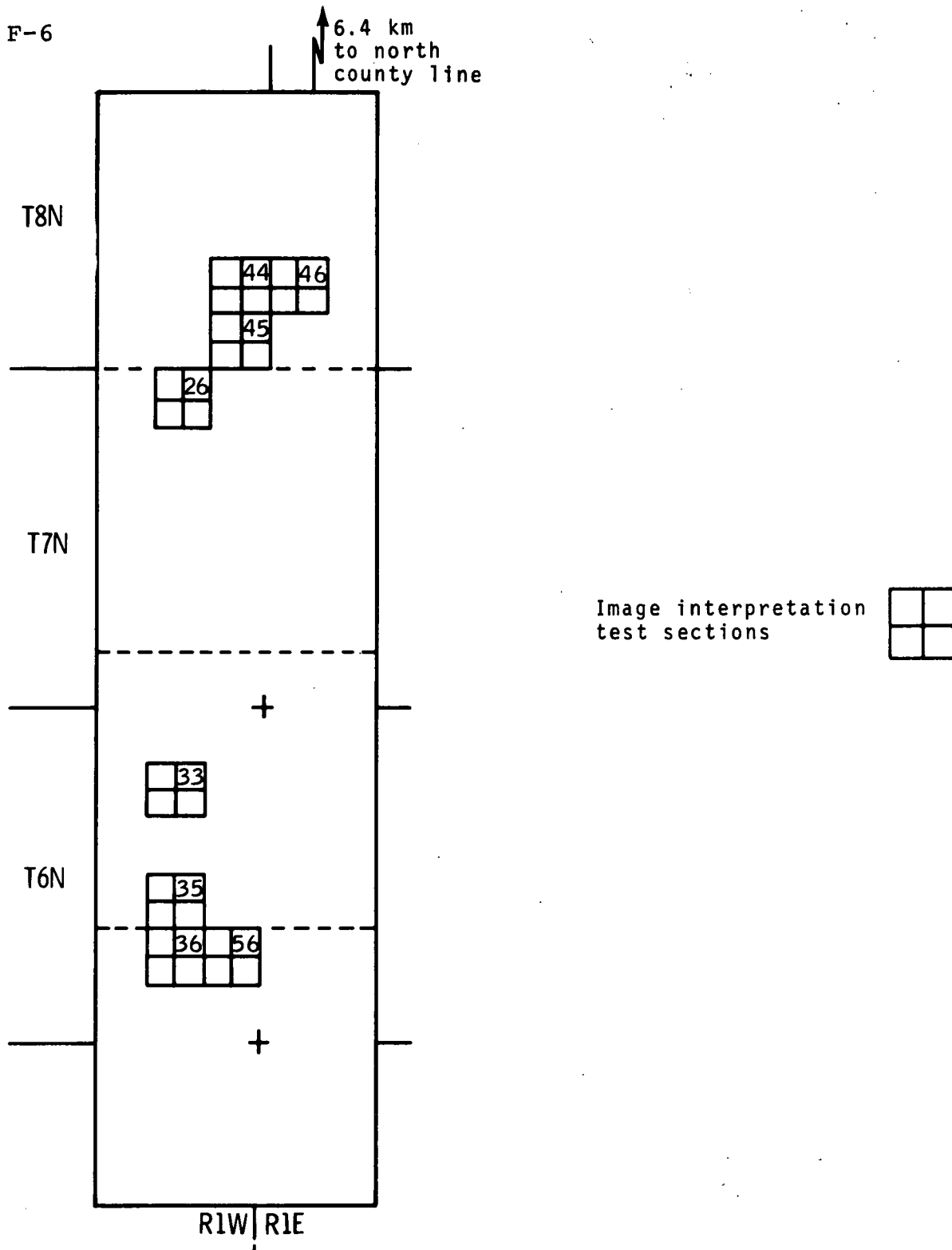


Figure F-5.- Idealized sketch of Fayette County ground investigation tracts.

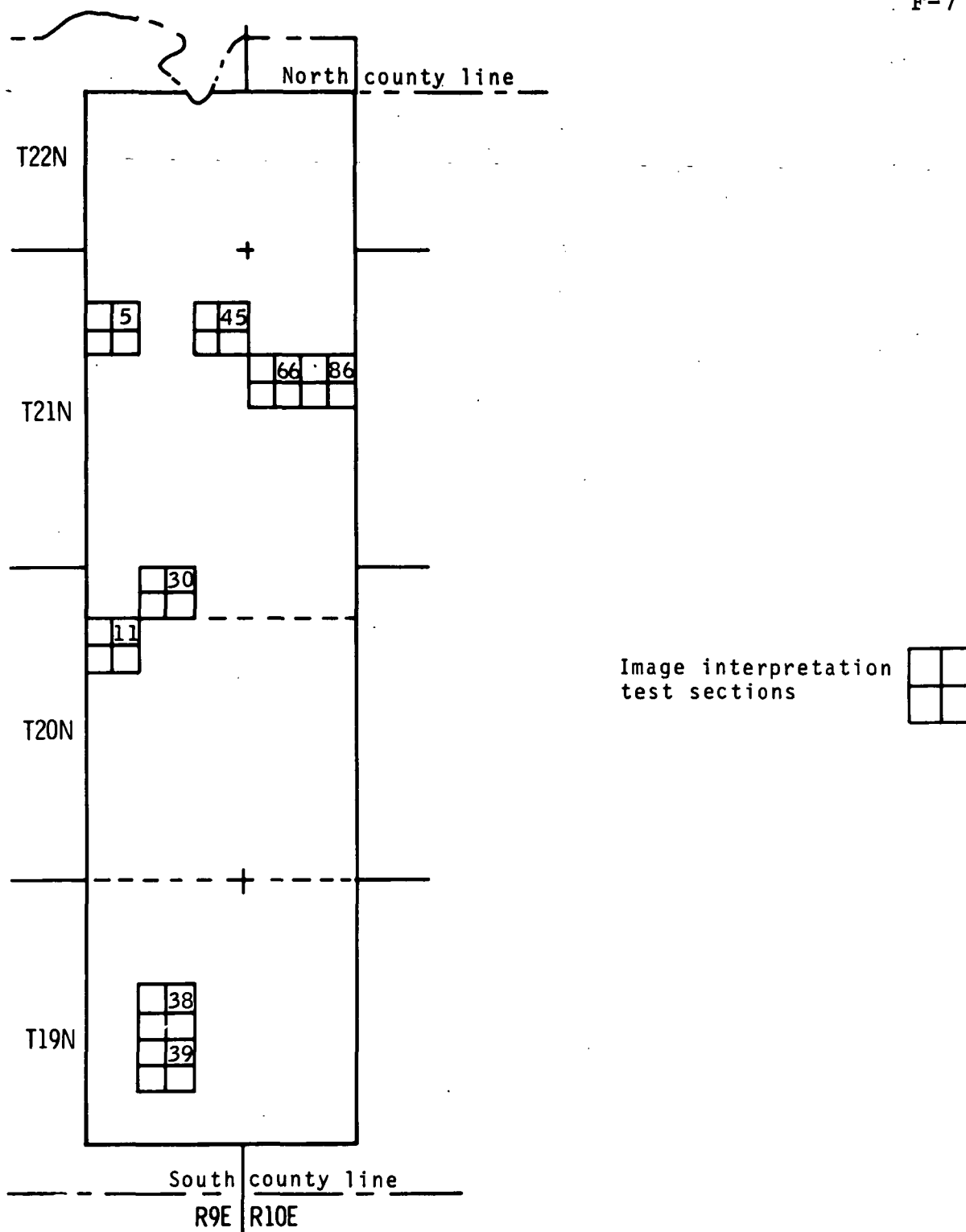


Figure F-6.— Idealized sketch of Lee County ground investigation tracts.

APPENDIX G

DATA SCREENING AND EVALUATION PROCEDURES

APPENDIX G

DATA SCREENING AND EVALUATION PROCEDURES

Each institution participating in CITARS will have the responsibility for data quality evaluation. However, problems detected at the ERIM, LARS, and EOD will be reported to the Technical Advisory Team for decisions on processing the data.

G.1 DATA QUALITY EVALUATIONS AT THE EOD

The aircraft photographic and MSS data (M²S, M-7, and 24-channel) will be evaluated in two simultaneous steps. The first will consist of visual observation of the photographic data. The second step will consist of multiphase evaluation of the electronic data. This evaluation will assess the capability of the aircraft data to support the project and accomplish the planned objectives.

G.1.1 Photographic Data

The Data Evaluation Team will evaluate visually all film products obtained during the flight missions over the six county segments. In each frame, the team will ascertain the status of cloud cover over the segment and the proper photographic coverage of the individual segment sections. For each mission, the team will identify each section on the photography and evaluate cloud cover and proper section coverage.

G.1.2 Electronic Data

The Data Evaluation Team will evaluate all electronic data collected from the aircraft missions over the six county segments. The evaluation will consist of three phases:

1. The team will verify the flight tapes. This quick-look test will evaluate the quality of the signal. The team will analyze the channel-to-channel registration and note data dropouts. This phase will determine the data usability.
2. From the flight tapes, the team will make a paper Visicorder strip map from the best channel of each mission. The strip will contain scan line counts and interranger instrument group time at appropriate intervals.
3. The team will identify and outline the individual test sections on the Visicorder strip. The quality and usability of the data and the extent of cloud and cloud shadow cover will be evaluated.

G.1.3 Reporting

One data quality report will be submitted at the end of the evaluation. The report will contain:

1. A list of the individual test sections within each county segment and information on cloud and cloud shadow cover, data coverage, and data quality.
2. Data evaluation for every multispectral channel on the quality of the signal, data dropouts, and status of registration among channels.

3. Comments on the usability of the data. Experienced analysts and laboratory personnel knowledgeable in the processing of multispectral data will evaluate the data usability.

G.2 DATA QUALITY EVALUATIONS AT LARS

G.2.1 ERTS Data

The ERTS MSS data will be evaluated in three steps. The first will be visual examination of image displays. Secondly, data statistics will be reviewed. Finally, the individual analyst teams will review the data.

G.2.1.1 Visual evaluation.-- Each channel will be inspected on the digital display. The inspector, an experienced ERTS data analyst, will note ERTS data problems, including poor scan lines, feature definition, evidence of calibration problems, test site coverage, and clouds. This subjective evaluation will rely on the inspector's ability to judge the data relatively according to the general or expected ERTS data set.

G.2.1.2 Statistical evaluation.-- For each channel, these statistics will be calculated: histogram, mean, variance, detector means, and variance of detector means. An experienced ERTS data analyst will review and evaluate the statistics, using typical ERTS MSS data statistics as a yardstick. Example indicators of poor or questionable data appear in table G-I. Data sets with questionable or poor statistical indicators will be reported to the project technical advisor.

G.2.1.3 Classification analyst evaluation.- Any data abnormalities noted by the classification analyst will be reported to the Data Evaluation Team for further consideration, and, when appropriate, these will be discussed with the technical advisor.

G.2.2 M-7 Scanner Data

The M-7 scanner data quality will be evaluated during the reformatting procedure. The three basic points of quality evaluation will include the analog A-scope visual screening, digital display image assessment, and data statistics review.

G.2.2.1 Analog screening.- During the analog-to-digital conversion step of data reformatting, each channel will be examined on an A-trace oscilloscope. Data abnormalities, such as excessive signal noise, data dropouts, and poor signal discrimination, will be noted.

G.2.2.2 Image assessment.- After the data are reformatted into LARSYS 3 format, the digital display will show each run for examination by an experienced analyst of M-7 scanner data. The analyst will view at least two channels of each run for the complete flight line and portions of all other channels. During this portion of data quality evaluation, attention will be given to test site coverage, atmospheric conditions below the aircraft, channel skew, scan-angle effects, black level calibration, and noise. Problems not reconciled in the reformatting process will be discussed with the project technical advisor.

G.2.2.3 Statistical evaluation.- During computer reformatting of each run, statistics are calculated for each data channel. The statistics include: the scene data variance; the average variance of scanner black level; the radiance lamp, Sun sensor, and thermal heat plate calibration sources; the means of calibration sources; and the signal-to-noise ratio. These statistics will be reviewed by an experienced analyst of ERIM data.

G.2.3 Reporting

All LARSYS multispectral image data storage tape runs are documented on a LARS form 17. Figure G-1 shows a sample of the form. The form is used to record run identification and descriptive information including data quality comments. A completed copy of this form will accompany each run shipped from LARS.

G.3 DATA QUALITY EVALUATIONS AT ERIM

G.3.1 ERTS Data

The ERTS data for each test segment will be received from LARS on nine-track, 314.9-bits/centimeter tapes in LARSYS format. These eight-bit data will be converted to the nine-bit ERIM format on seven-track, 314.9-bits/centimeter tapes.

G.3.1.1 Gray maps of all channels.- For each of the four channels, a digital map of each segment will be generated. Each map will cover all lines and points on the data tape. The maps will be generated using the MAP program with its standard gray-tone darkness symbols for nine levels.

The signal levels assigned to each of the nine gray-map levels will be determined separately for each channel. With the automatic level-set option of the MAP program, the levels will be based on a sample of points throughout the entire area of the test segment rectangle. The levels for each channel will be based when running the MAP program, using the following settings:

LMODE=2

NLEVEL=9

SSA=1,0,1,1,0,1

The gray maps will be examined for evidence of striping, banding, or signal breakup.

G.3.1.2 Histograms, means, and standard deviations of detector data.- The STAT program will be run separately for each detector with the option NOEDIT=\$ON\$ over the entire area of the test segment rectangle. Each of the six possible sets containing every sixth scan line of data will be specified NSA=n,0,6,1,0,1 where n is the first...sixth scan line in the rectangle. This specification will generate 24 histograms, the number of data pixels at each signal level. Each of the six detectors in each of the four channels will have a histogram. The corresponding 24 signal means and standard deviations will also be computed.

G.3.1.3 Variances of detector means.- The data means generated will be compared quantitatively among the six detectors in each channel. As a standard for comparison, a combined mean and standard deviation about that mean will be determined for each combination of five detectors.

A two-sided t-test with a (0.95) confidence level will be applied to the mean for each remaining detector. (Note: Values underlined within parentheses throughout these procedures are parameters which are subject to change as experience is gained on the project. All final data will be processed uniformly.) When the mean of a detector is rejected, the procedure will be repeated with one less detector. For example, if $\left[C_j^i\right]_j^6 = 1$ denotes the collection of all combinations of the six channel i detectors taken five at a time, $C_1^i = D_1^i, D_2^i, D_3^i, D_4^i, D_5^i, \dots$ where D_k^i denotes the k th detector for channel i . Then R_j^i will denote the ensemble of five mean signal values measured by C_j^i , a particular combination of five detectors over the segment.

1. For each ensemble R_j^i , the mean μ_j^i and standard deviation σ_j^i will be computed.
2. For each C_j^i in channel i , $\left|\mu_j^i - \hat{\mu}_j^i\right| = \Delta_j^i$ will be computed, where $\hat{\mu}_j^i$ is the previously calculated mean of data from the detector not included in C_j^i .
3. If $\Delta_j^i > \underline{(2.57)} \sigma_j^i$, data from the detector will be rejected.
4. If a detector mean fails the test, the procedure will be repeated for the remaining N detectors with $j = N$ and a rejection criterion, $\Delta_j^i > \lambda \sigma_s^i$, where λ is the appropriate multiplier for a two-sided t-test with a (0.95) confidence level.

G.3.1.4 Technical Advisory Team.- An experienced analyst will examine the histograms. The Technical Advisory

Team will consider any data rejected by the analysis and any other evidence of data defects which experienced analysts believe might deleteriously affect subsequent processing. The Technical Advisory Team will rule either that the data tapes should be regenerated where possible to remedy the problem or that any data determined to be defective should be excluded from further processing at the EOD, ERIM, and LARS.

G.3.2 Aircraft MSS Data

G.3.2.1 Data reformatting.- Aircraft data are expected to be received in LARSYS 3 format and will be converted to ERIM format.

G.3.2.2 Field coordinate conversion.- The locations of all training and test fields, quarter sections, sections, and other larger areas, such as 3-by-3 sections, are expected to be received from LARS in coordinates that match the LARSYS 3 formatted data tapes. These coordinates will be converted to ERIM's 'NSA' card format.

G.3.2.3 Data quality verification.- Some standard data quality checks are expected to be made by EOD during tape conversion. Some of the ERIM standard monitoring of the data quality will be applied also, in order that any problems can be brought to the attention of the Technical Advisory Team before further processing.

G.3.2.4 Gray map generation.- Digital gray maps will be generated for the 20 test sections for two channels in the red and infrared portions of the spectrum (the exact wave bands

will depend on the scanner used). Nine levels will be used with the standard darkness symbols; the levels will be determined separately for each channel by the automatic level-set feature.

In addition, gray maps of a smaller selected test area will be generated for all channels for use in the skew check. The area will contain road or other sharp boundaries between contrasting features.

G.3.2.5 Histograms, means, and standard deviations.- The STAT program will be run without editing (NOEDIT=\$ON\$) over a selected test area to generate one histogram per channel, plus signal means and standard deviations.

G.3.2.6 Skew check.- The gray maps will be examined to ascertain whether the contrast boundaries fall on the same pixels in all channels; if they fail to do so in any channel, the amount of deviation determines the skew of that channel relative to the others.

G.3.2.7 Technical Advisory Team.- The histograms and gray maps generated above will be examined by an experienced analyst for signs of defective data. If, in the analyst's judgment, there is evidence of data defects or skew which might deleteriously affect subsequent processing, this will be reported to the Technical Advisory Team.

TABLE G-I.- STATISTICAL INDICATORS OF
QUESTIONABLE ERTS DATA QUALITY

| <u>Statistical indicators</u> | <u>Possible error</u> |
|---|--|
| Peak detector mean difference for a channel greater than 2.0. | Improper calibration; lines of field probably will not classify properly. |
| Abnormally high mean and low variance. Typical for channel 1: $M > 30$; $V < 10$. | Uniform haze or overcast atmospheric condition; images will have lower than normal contrast. |
| Peaks at histogram high radiance end, especially channel 1. | Indicates clouds. |

Aircraft Data Storage Tape File

Run Number: _____ Flightline Identification: _____
 Date Tape Generated: _____ Date Data Taken: _____
 Tape Number: _____ Time Data Taken: _____ hours
 File Number: _____ Aircraft Altitude: _____ feet
 Lines of Data: _____ Ground Heading: _____ °
 Seconds of Data: _____ Field of View: _____ radians
 Miles of Data: _____ Data Samples Per Channel Per Line: _____
 Line Rate: _____ lines per sec. Sample Rate: _____ milliradians

Spectral Bandwidth in Micrometers:

| Chan | Lower | Upper | Chan | Lower | Upper | Chan | Lower | Upper |
|------|-------|-------|------|-------|-------|------|-------|-------|
| (1) | _____ | _____ | (2) | _____ | _____ | (3) | _____ | _____ |
| (4) | _____ | _____ | (5) | _____ | _____ | (6) | _____ | _____ |
| (7) | _____ | _____ | (8) | _____ | _____ | (9) | _____ | _____ |
| (10) | _____ | _____ | (11) | _____ | _____ | (12) | _____ | _____ |
| (13) | _____ | _____ | (14) | _____ | _____ | (15) | _____ | _____ |
| (16) | _____ | _____ | (17) | _____ | _____ | (18) | _____ | _____ |
| (19) | _____ | _____ | (20) | _____ | _____ | (21) | _____ | _____ |
| (22) | _____ | _____ | (23) | _____ | _____ | (24) | _____ | _____ |
| (25) | _____ | _____ | (26) | _____ | _____ | (27) | _____ | _____ |
| (28) | _____ | _____ | (29) | _____ | _____ | (30) | _____ | _____ |

Data Run Conditions:

Data Tape Comments:

Figure G-1.- LARS form 17, record of aircraft storage tape file.

APPENDIX H
DATA PREPARATION PROCEDURES

APPENDIX H

DATA PREPARATION PROCEDURES

H.1 REFORMATTING OF M²S DATA

Data from the M²S scanner will be received by EOD in a PCM format and converted to LARSYS 3 format on the EOD DAS. The PCM data tapes will contain 838 eight-bit words per scan, of which 803 words will be radiometric scene data. In conversion to LARSYS 3, 808 words per scene will be preserved, including 802 words of radiometric scene information and 3 calibration-source-weight words and their 3 associated variances.

H.2 REFORMATTING OF M-7 AIRCRAFT MSS DATA

The ERIM MSS data will be converted to LARSYS 3 format by analog-to-digital conversion and computer reformatting. The first conversion will be done by the LARS Analog-to-Digital Conversion System, which will (1) reproduce duplicate ERIM system, 14-track, analog magnetic tapes at 9.52 centimeters/second (one-sixteenth of real time), (2) sample each channel of selected scan lines to eight-bit resolution, and (3) record the bulk data on seven-track digital tapes with 314.9-bits/centimeter density. In the process, the scene and Sun-sensor signals will be sampled at a 3-milliradian rate referenced to the scanner rotation in synchronization with the roll-corrected scanner marker pulse. The lamp and two thermal calibration sources will be sampled in synchronization with the scanner marker pulse at a 6-milliradian rate. The channel deskew pulse will be sampled at a 3-milliradian rate in synchronization with the scanner marker pulse.

The computer reformatting of ERIM data will include measurement of calibration sources, deskewing and line-to-line alignment of scene data, and formatting the data into LARSYS 3 format for output onto 630 bits/centimeter, nine-track tapes. In this process, a header record will be generated from card input information and typical calibration values for the beginning of the run. For each bulk-sampled scan line of data: the calibration source values will be measured and stored; the aircraft roll parameter will be derived from the Sun-sensor signal and stored; a channel des skew parameter will be derived for each data channel from the scanner deskewing pulse; a line-to-line alignment parameter will be derived from the lamp signal; and the scene data and associated parameters will be formatted for output onto digital tape. After each run is reformatted, a summary of data parameters will be printed for evaluation of the reformatting performance and completion of a LARS form 17 for the LARS MIST library logbook.

H.3 PREPARATION OF ERTS DATA

All LARS preprocessing and analysis procedures, such as registration, rotation, scan-angle correction, clustering, and classification, will be performed on data stored in the LARS MIST library. The library is the common data base, and all remote sensing data received for analysis must be converted to LARSYS 3 format for storage in the library.

The ERTS system-corrected image CCT data are converted to LARSYS 3 format by a simple copy process which will generate a LARSYS run header record, copy the specified portion of the ERTS CCT's into LARSYS 3 format, and print documentation of the reformatting.

The LARSYS run identification or header record will be generated from information from the ERTS CCT annotation record, punched card input, and the computer-stored date. Data records and record segments will be selected according to the frame area requested for reformatting via control cards. Selected samples of each selected scan line will be rearranged into the sequence required by LARSYS and written on the LARSYS tape. After the selected area is reformatted, documentation of the frame and the reformatted area will be printed on the line printer. In addition, a document in the format of the LARS form 17A will be printed and catalogued in the LARS MIST library logbook.

H.4 GEOMETRIC CORRECTION OF ERTS DATA

In certain cases, the scale and skew distortion in ERTS bulk (sensor-processed) data should be corrected and rotated to a north-oriented geographic grid. The following single linear coordinate transformation will remove most of the distortion and implement a rotation.

H.4.1 Scale Correction

The ERTS bulk data will have an approximate horizontal scale of 57 meters/point and a vertical scale of 80 meters/point. These images, when observed on the digital display, will be badly distorted; and photographs taken from the display will contain this approximate 3:2 distortion. Correction of the original scale to a uniform scale in each direction will produce square images on the digital display.

The rescaling transformation is

$$X = AY$$

$$X_1 = a_{11}Y_1$$

$$X_2 = a_{22}Y_2$$

$$A = \begin{bmatrix} a_{11} & 0 \\ 0 & a_{22} \end{bmatrix} \quad (H-1)$$

where Y is in the new coordinate system, y_1 is the horizontal axis, X is in the old or input coordinate system, and A is the scale factor matrix.

For example, to correct the horizontal scale to be the same as the vertical scale, the y_1 multiplier is 1.328, and the y_2 multiplier is 1; or

$$A_1 = \begin{bmatrix} 1.328 & 0 \\ 0 & 1 \end{bmatrix} \quad (H-2)$$

This would make the horizontal and vertical scale 80 meters/point.

An image corrected with this matrix would be square on the display but distorted on the line printer. In fact, the 3.15-line/centimeter and 3.9-column/centimeter aspect ratio of the computer line printer will almost correct for the ERTS scale inequality. The remaining scale differential on the

line printer will be $0.8 \times 1.328 = 1.062$. The corresponding matrix for correction of the ERTS data to spatial equal scale on the line printer will be

$$A_1 = \begin{bmatrix} 0.8 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1.328 & 0 \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} 1.062 & 0 \\ 0 & 1 \end{bmatrix} \quad (H-3)$$

Two data sets must be created on the display and line printer if equal scale is desired. One set applies the 1.328 horizontal scale factor, and the other applies 1.062.

H.4.2 Earth Rotation Skew Correction

The Earth rotates under the ERTS as ERTS scans successive lines. The velocity of the Earth's surface beneath the satellite is approximately

$$V_e = R_e \cos \lambda \omega_e \quad (H-4)$$

where

V_e = the velocity to the east

R_e = the radius of the Earth at latitude λ

λ = the latitude

ω_e = the angular rate of the Earth, which is
0.00007272 radians/second

At latitude 40° N. and with the equatorial Earth radius of 6,378,160 meters, the surface velocity is
 $463.82 \cos \lambda = 355.29$ meters/second .

Because the satellite period is 106 minutes, the angular rate $\omega_o = 0.000987$ radians/second . A 161-kilometer frame is scanned in

$$t_s = L/R_e \omega_o = \frac{161,000}{63,781,600 \times 0.000987} = 25.5 \quad (\text{H-5})$$

where t_s is time in seconds and L is the ground distance in meters.

The lateral displacement of the scene during the scanning of one frame is

$$\Delta X_1 = t_s V_e = 8,060.5 \text{ meters} \quad (\text{H-6})$$

This is $8.06 \div 161$ or 5 percent of the frame size. The correction matrix for this effect must shift the bottom of the frame 8,060.5 meters east with respect to the top. This shift will be accomplished by the matrix

$$A_2 = \begin{bmatrix} 1 & 0.05 \\ 0 & 1 \end{bmatrix} \quad (\text{H-7})$$

H.4.3 Frame Rotation

In some cases the image should be rotated so that north will be at the top. A standard coordinate transformation will be used to rotate the ERTS data clockwise by an angle θ to compensate for the fact that meridians

cross the vertical axis at an angle of $-\theta$ because of the particular orbit geometry. The rotation matrix will be

$$A_3 = \begin{bmatrix} \cos \theta & \sin \theta \\ -\sin \theta & \cos \theta \end{bmatrix} \quad (H-8)$$

For a 14° rotation, the matrix values will be

$$A_3 = \begin{bmatrix} 0.9703 & 0.2412 \\ -0.2412 & 0.9703 \end{bmatrix} \quad (H-9)$$

The angle of the satellite ground track with the Earth meridian will vary from 9.114° at the Equator to 90° at the highest latitude in the orbit. The angle of the ground track as a function of latitude is

$$\theta = 90 - \cos^{-1} \left[\frac{\sin \theta_E}{\cos \lambda} \right] \quad (H-10)$$

where θ_E = the orbit angle with a meridian at the Equator (9.119°) and λ = the latitude for $\lambda = 40^\circ$, $\theta = 11^\circ 56'$; and for $\lambda = 45^\circ$, $\theta = 12^\circ 57'$.

H.4.4 Rescaling

Many researchers relate maps of various kinds to line printer pictorial printouts of ERTS imagery for the location of training areas and evaluation of results. The evaluations are performed more easily if the map and the data printout

have the same scale so that a transparent overlay can be made from the map and placed on the data printout. Rescaling can be accomplished by adding a scale factor matrix to the other matrices used. When corrected to 80 meters/point in the vertical dimension as described above, the scale of the imagery will have a map scale of 1 centimeter = 25,190.4 centimeters. To correct this scale to that of the 7.5-minute series 1:24,000-scale topographic maps, a factor of $24,000 \div 25,190.4 = 0.952$ must be included. The matrix to be used would be

$$A_4 = \begin{bmatrix} 0.952 & 0 \\ 0 & 0.952 \end{bmatrix} \quad (H-11)$$

Other scale factors could be generated by using the appropriate constant in a diagonal matrix as shown.

The corrections described by the above matrices are made in one operation by multiplying them together in the appropriate order.

The transformation matrix will transform the coordinates of the original ERTS data into a new system having approximately the desired properties. Many errors will remain after the transformation. Random geometric distortions because of sensor scan errors, satellite attitude errors, orbit variation effects, and other factors will still exist. In the transformation, data points will be required from locations between existing ERTS samples where no data are available. These points can be obtained by interpolation or by using the nearest neighbor rule, sometimes called zero-order interpolation. This problem is discussed briefly next.

The resolution and sampling scheme for the ERTS MSS system is such that resolution elements are approximately 80 meters in diameter and are spaced 57 meters apart across track and 80 meters apart along track. The sample arrangement is depicted in figure H-1. Geometrical transformation of ERTS MSS digital data will be performed by LARS in certain cases; and, in doing so, samples between existing sample points in the original data will be needed. To avoid altering the spectral response of any sample, no interpolation will be performed to produce the required new sample. Instead, the desired point will be chosen as the nearest available point in the original data. Figure H-2 illustrates this nearest neighbor rule. The nodes of grid A represent the original ERTS data points, and the uniform grid B represents the desired points in the transformed data. The arrows represent the locations from which data were taken to supply data to the new grid points under the nearest neighbor rule. The largest position error will occur when the required new point lies at the center of an original grid cell. The position error will be bounded by

$$0 \leq \epsilon_T \leq \frac{1}{2} \sqrt{\delta L^2 + \delta C^2} = \xi_{\max} \quad (\text{H-12})$$

where ϵ_T = the Euclidian error distance , δL = the along track or line spacing of original samples , δC = the across track or column spacing of the original samples for the present ERTS data , and ξ_{\max} = the upper bound for position errors . For the present ERTS data, $\delta L = 80$ meters , $\delta C = 57$ meters , and $\xi_{\max} = 49.2$ meters . What is the distribution of errors over the interval $(0, \xi_{\max})$? The error

for each point can be computed explicitly. The locations of required points from the original data are given by the transformation

$$\begin{aligned} X_L &= f_L(y_L, y_C) \\ X_C &= f_C(y_L, y_C) \end{aligned} \quad (H-13)$$

where $y_{L,C}$ = the line and column coordinates of the new data set, and $X_{L,C}$ = the coordinates of required points in the old original data set.

The new or y coordinates are integer line and column numbers. Thus, $y_{L,C} = 1, 2, \dots, N$. In general, $X_{L,C}$ will represent real numbers. The error under the nearest neighbor rule will be:

$$\begin{aligned} \epsilon_L &= \begin{cases} \epsilon = X_L - [X_L] \\ \text{If } 0 \leq |\epsilon| \leq 0.5, & \epsilon_L = |\epsilon| \\ \text{If } 0.5 < |\epsilon| < 1, & \epsilon_L = |\epsilon| - 1 \end{cases} \\ \epsilon_C &= \begin{cases} \epsilon = X_C - [X_C] \\ \text{If } 0 \leq |\epsilon| \leq 0.5, & \epsilon_C = |\epsilon| \\ \text{If } 0.5 < |\epsilon| \leq 1, & \epsilon_C = 1 - |\epsilon| \end{cases} \end{aligned} \quad (H-14)$$

where $[X]$ denotes the greatest integer less than X .

For image rotation, deskewing, and rescaling, a linear transformation of the form:

$$X_L = a_{11}Y_L + a_{12}Y_C$$

$$X_C = a_{21}Y_L + a_{22}Y_C \quad (H-15)$$

will be used. A discussion of geometric corrections will appear in another report. For a rotation of approximately 12° , rescaling to a line printer scale of 1 centimeter = 24,000 centimeters, and deskewing 5 percent, which is typical of operations for ERTS data, the transformation will be:

$$\begin{bmatrix} X_L \\ X_C \end{bmatrix} = \begin{bmatrix} 0.97 & -0.194 \\ 0.41 & 1.059 \end{bmatrix} \begin{bmatrix} Y_L \\ Y_C \end{bmatrix} \quad (H-16)$$

The distribution was evaluated using a simple program which computes the error mean and distribution for 1,000 values of Y_L and 1,000 values of Y_C for a total of 10^6 points. The results are in table H-I. The mean is 0.23 for each dimension, which agrees with the theoretical mean of 0.25. The average distance error is

$$\bar{\epsilon}_T = \sqrt{(80 \times 0.23)^2 + (57 \times 0.23)^2} = 22.4 \text{ meters} \quad (H-17)$$

On the average, about 22 meters of position error will be introduced by geometric transformation of ERTS data using the nearest neighbor rule. This error will be only slightly more than the 15.2-meter tolerance for 1:24,000-scale topographic maps of the U.S. Geological Survey (table H-I).

H.5 TEMPORAL OVERLAY

The overlay processing will consist of image correlation and overlay transformation performed sequentially. The overlay operation will align precisely two digital multispectral images of the same area taken at two different times. Many factors will prevent the exact overlay of the images, making this operation approximate. For example, it is unlikely that the samples from one time will be imaged from exactly the same area as samples from a later satellite pass. In general, no data exist which will exactly overlay for both times, even if no other errors are present. Sources of error will be changes in the scene and other noise sources which will prevent exact correlation or matching of the two images. The overlay procedure will consist of the following.

Initial checkpoints or matching points will be selected manually in the two images to be overlaid, using the LARS digital display. At least seven points will be found, and the coordinates will be recorded on punched cards. Each checkpoint will consist of an ordered quadruple of coordinates

$$P_k = \left[X_A^{(k)}, Y_A^{(k)}, Y_B^{(k)}, Y_B^{(k)} \right] \quad (H-18)$$

where

X_A, Y_A = the coordinates of a point in the A or reference image

X_B, Y_B = the coordinates of the corresponding point in the B image to be overlaid on the A image.

A two-dimensional, least squares, quadratic polynomial of the following form will be generated to calculate the differences in positions of points in the A and B images.

$$\begin{aligned}\Delta X &= a_0 + a_1x + a_2y + a_3x^2 + a_4y^2 + a_5xy \\ \Delta Y &= b_0 + b_1x + b_2y + b_3x^2 + b_4y^2 + b_5xy\end{aligned}\quad (H-19)$$

The least squares solution for the coefficients will be

$$\begin{aligned}A &= (P^T P)^{-1} P^T \delta_x \\ B &= (P^T P)^{-1} P^T \delta_y\end{aligned}\quad (H-20)$$

where A and B are 6-by-1 column vectors for a_i, b_i , $i = 1, \dots, 6$, P is the matrix of powers of X and Y for each checkpoint, and $\delta_{x,y}$ is an N-by-1 column vector of the differences between the A and B coordinates.

$$\delta_{x_i} = X_{B_i} - X_{A_i}$$

$$\delta_{y_i} = Y_{B_i} - Y_{A_i}$$

$$i = 1, \dots, N \quad (H-21)$$

$$P_{ij} = x_i^k y_i^\ell \quad (H-22)$$

where

i = the number of the checkpoint, $i = 1, \dots, N$

$k = 0, 1, 0, 2, 0, 1$

$\ell = 0, 0, 1, 0, 2, 1$ for $j = 1, 2, 3, 4, 5, 6$, respectively

This function describes an approximate overlay of A and B.

A block image cross-correlator is employed to find the remaining image displacements at the nodes of a uniform grid using the approximate overlay, two-dimensional, least squares, quadratic polynomial. The correlator implements the correlation coefficient equation

$$R(k, \ell) = \frac{E \left[(X_A - \eta_A) (X_{B_{k, \ell}} - \eta_B) \right]}{E \left[(X_A - \eta_A)^2 \right] \times E \left[(X_{B_{k, \ell}} - \eta_B)^2 \right]} \quad (H-23)$$

where

E = mathematical expectation

$\eta_{A,B}$ = the mean values of A and B data blocks

k, ℓ = the shift of the Y block with respect to the X block
of k rows and ℓ columns

This will obtain as large a set of correlations as possible within computation time constraints. The k, ℓ values at the maximum R are chosen as the correct shift to match the block from image B to the block from image A. This peak will be interpolated using three-point LaGrange polynomials to produce a fractional estimate of shift. The set of shifts from the correlator is added to the shift values from the original polynomial to form a new set of checkpoints.

A new overlay polynomial will be generated from the correlator-produced set of checkpoints and used actually to overlay the images. The nearest neighbor rule will be employed as in the geometric correction process to obtain points where no data exist. The A and B images will be combined onto one data tape, and a new LARS MIST file will be formed having $M + N$ channels, where M is the number of channels from image A and N is the number of channels from image B.

The overlay data tape will be inspected statistically and visually on the digital image display system to check image quality and overlay quality. Precise evaluation of overlay accuracy will not be possible. A measure of error will be obtained from the residuals of least squares polynomial generation, and this figure averages 0.5 image sample root mean square.

H.6 EFFECTS OF GEOMETRIC TRANSFORMATIONS ON CIP

Several methods of data preparation have been proposed and used for analysis of ERTS data. Three methods are described here for consideration with this project.

1. Method 1:

- a. Locate the segment in the image and reformat the smallest portion of the ERTS frame which includes the segment.
- b. Locate all test and training fields in the segment.

2. Method 2:

- a. Locate the segment in the image and reformat the smallest portion of the ERTS frame which includes the segment.
- b. Deskew, rescale, and rotate the portion of the frame selected and document the transformation.
- c. Locate all test and training fields in the segment using the resulting data set.

3. Method 3:

- a. Locate the segment in an image and reformat the smallest portion of the ERTS frame which includes the segment.
- b. Overlay the data set to a set which was obtained from method 1 over the same segment and which was processed according to method 2.
- c. Deskew, rescale, and rotate the resulting data set using the same transformation as in method 2.
- d. Use the test and training field samples obtained from method 2.

Method 1 has been used in most analysis experiments. However, methods 2 and 3 have been tested and shown to be feasible in some experiments. Because of the increased ease of locating deskewed and rescaled test and training fields and rotated data sets, most analysts prefer method 2 when studying several data sets taken over the same ground location. When studying several data sets, the analysts prefer method 3 because it eliminates the variability in experimental results due to the location and preparation of training and test fields.

H.7 EFFECT OF PROCESSING ON ANALYSIS RESULTS

Since methods 2 and 3 alter the data originally delivered for machine processing, the effect of this processing on the analysis results has been questioned. The following four hypotheses will be tested statistically:

1. The results of analysis using data prepared by method 1 are equivalent to the results of analysis using data prepared by method 2 with respect to CIP.
2. The results of analysis using data prepared by method 1 are equivalent to the results of analysis using data prepared by method 2 and equivalent to the results of ground observations with respect to the percent of the segment in each class.
3. The results of analysis using data prepared by method 1 are equivalent to the results of analysis using data prepared by method 3 with respect to CIP.
4. The results of analysis using data prepared by method 1 are equivalent to the results of analysis using data

prepared by method 3 and equivalent to the results of ground observations with respect to the percentage of the segment in each class.

The procedure for testing these hypotheses is a comparison of LARSYS classification results using unaltered and altered data. In the reference case using unaltered data, the agricultural test fields will be obtained by manual inspection of pictorial reproductions of the digital data. In the altered data case, fields will be picked manually from the geometrically transformed data. The LARSYS 3 classification process will be executed on both data forms, and the results will be compared statistically. The experiment will be repeated for six test segments.

For the second ERTS pass, the new data will be geometrically registered and corrected with the initial or reference data. Test fields defined in the reference data will be defined in the new data by virtue of the registration or overlay process. The classification comparison will be done using the fields obtained from the registration and those obtained manually by inspection of the new data. These processes will produce a classification for each trial.

The fields obtained by methods 1, 2, and 3 will be classified using LARSYS 3 and the analysis procedure defined earlier. Results of the classification will be an overall percentage of correct recognition of the four defined classes, corn, soybeans, wheat, and "other," and the total points in each class in the entire segment.

The experiment will be repeated for several segments. For the first trial, when only one data set is available for each segment, methods 1 and 2 will be performed. For the second coverage obtained for each segment, methods 1 and 3 will be executed. The results will be compared statistically with results using method 1 as a base. The results of the analysis will substantiate or negate hypotheses 1 through 4. If negation occurs, results will be evaluated to determine whether the method in question is superior or inferior to method 1.

TABLE H-I.— DISTRIBUTION OF POSITION ERRORS FROM ONE MILLION
ERROR CALCULATIONS

| <u>Interval</u> | <u>Count for line errors*</u> | <u>Count for column errors[†]</u> |
|-----------------|-------------------------------|--|
| 0 — 0.05 | 99,953 | 99,850 |
| 0.05 — 0.10 | 100,042 | 100,100 |
| 0.10 — 0.15 | 100,014 | 100,100 |
| 0.15 — 0.20 | 100,017 | 100,100 |
| 0.20 — 0.25 | 99,811 | 99,609 |
| 0.25 — 0.30 | 100,104 | 100,092 |
| 0.30 — 0.35 | 100,035 | 100,100 |
| 0.35 — 0.40 | 100,053 | 100,100 |
| 0.40 — 0.45 | 100,005 | 100,100 |
| 0.45 — 0.50 | 99,966 | 99,849 |

*Mean error in lines = 0.23 . Root mean square error in lines = 0.28 .

[†]Mean error in columns = 0.23 . Root mean square error in columns = 0.28 .

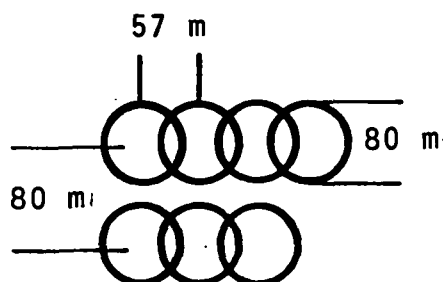


Figure H-1.— ERTS MSS sample geometry.

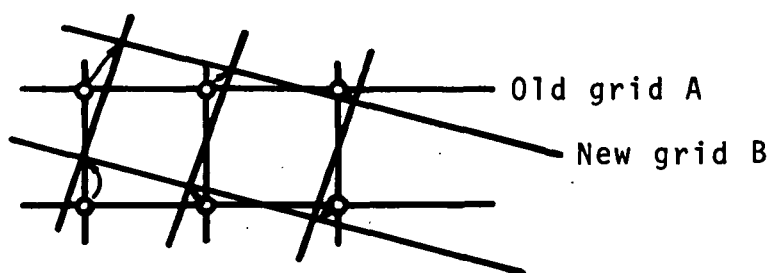


Figure H-2.— Transformation illustration.

APPENDIX I

PROCEDURES FOR EOD ADP

APPENDIX I
PROCEDURES FOR EOD ADP

I.1 ERTS-EOD-SP1

I.1.1 Local Recognition Processing

The steps described here are designed to reflect analyst interaction with menus and reports which will be displayed on a CRT device via a keyboard and graphicon pen under control of an IBM 360-75 computer and associated software. This system was implemented at NASA/JSC for the EOD and is denoted ERIPS. The system and its operational usage are documented in the *ERIPS Requirements Document*, PHO-TR514, March 1973, and in the *ERIPS User's Guide*, Volume I, revised July 1973.

I.1.1.1 Sign-on to ERIPS.- The analyst will sign on to ERIPS and load the appropriate image tape using the nomenclature system for image set identifier.

Image set identifier: CO:S:P:T:A:MD

CO refers by county to the segment being processed. The designations for CO are:

| <u>County</u> | <u>CO</u> |
|---------------|-----------|
| Lee | LE |
| Livingston | LI |
| Fayette | FA |
| Huntington | HU |
| Shelby | SH |
| White | WH |

S refers to sensor type. The designations for S are:

| <u>Sensor</u> | <u>S</u> |
|------------------|----------|
| ERTS | 1 |
| M ² S | 2 |
| MSDS | 4 |
| M-7 | 7 |
| EREP | 9 |

P refers to single or multiple data cycle numbers. The designations for P are:

| <u>Process</u> | <u>P</u> |
|------------------------------|----------|
| Single-pass cycle 3 | 3 |
| Multiple-pass cycles 2 and 5 | A* |

T denotes either local training/local recognition or local training/nonlocal recognition. The designations for T are:

| <u>Process</u> | <u>T</u> |
|-------------------------------------|----------|
| Local training/local recognition | L |
| Local training/nonlocal recognition | N |

A denotes whether this is an original process of this data set or a restart under the nonlocal recognition phase. The designations for A are:

| <u>Process</u> | <u>A</u> |
|----------------|----------|
| Original | O |
| Restart | R |

MD is the month and day of the month of this processing run.

*Multitemporal analysis activity will be denoted by an alphabetic character, A, B, C, ... assigned to a particular data set prior to actual processing.

I.1.1.2 Pattern recognition and image display.- The analyst will enter pattern recognition, proceed to image display, and

1. Generate a gray-scale image of the segment J* from a histogram of the first 50 lines of ERTS band 1.
2. Examine the 16 displayed gray-level images to verify correct scene loading. Variances such as noise and clouds should be noted and recorded for submission to the Technical Advisory Team.
3. Repeat steps 1 and 2 for ERTS bands 2 to 4.

I.1.1.3 Training field selection.- The analyst will return to pattern recognition and

1. Enter all training fields for corn, soybeans, and wheat via the keyboard, using the LARS list for field boundary coordinates. [NOTE: If the Technical Advisory Team determines that an insufficient number of training fields exist in segment J for one of the major crops (that is, corn, soybeans, or wheat) to meet the task objectives, it may recommend that these training fields be included with the training fields for the class "other."]
2. Enter all training fields for the classes "other" via the keyboard, using the list of field boundary coordinates from LARS.
3. Enter the entire 8- by 32-kilometer segment J as a test field; although this is not required for the project

*Alphabetic characters for segments or classes are variables used to depict a particular segment or class for discussion purposes only.

analysis of variance, it will be utilized as a record for postprocessing evaluation and review and for historical reference.

I.1.1.4 Statistics.- The analyst will return to pattern recognition, and

1. Generate class statistics for all classes, as defined in section I.1.1.3; this will produce initialization means for subsequent clustering processes.
2. Produce a class statistics report and hard copies for postanalysis review.

I.1.1.5 Clustering.- The analyst will return to pattern recognition to enter clustering data. This process will produce class statistics for corn, soybeans, and wheat using the ERIPS-implemented version of ISOCLS. The analyst will

1. Initiate the clustering processor for the class corn using all channels, $STDMAX = 3.2$, $DLMIN = 3.2$, $NMIN = 3.0$, and $ITMAX = 5$. The use of these parameters and the specific values assigned to each are discussed in *The JSC Clustering Program ISOCLS and Its Applications*, LEC-0483, July 1973. In general, these parameters will allow the user flexibility in streamlining the clustering process to fit his particular application requirements as described below.

| <u>Parameter</u> | <u>Description</u> |
|------------------|--|
| STDMAX | This parameter will examine the standard deviation from the mean of each cluster resulting from one complete cycle (iteration) through the data. Each cluster having a |

ParameterDescription

standard deviation greater than the user-designated value for STDMAX will be split into two clusters. The data points will be reassigned by a distance measure incorporated in the ISOCLS logic. New means and standard deviations will be computed for the new clusters, and the process will be reiterated.

DLMIN

This parameter will examine the means of each cluster resulting from each iteration. If two clusters are separated by a shorter distance than the user-designated value for DLMIN, they will be combined to form one cluster. Again, new means and standard deviations will be computed for each new cluster, and the process will be reiterated.

NMIN

This parameter will define the minimum number of points a unique cluster may contain. Any cluster resulting from a clustering iteration which contains less than the user-designated value for NMIN will be deleted, and the points will be reassigned to the next nearest cluster. The process will then be reiterated.

ITMAX

This parameter defines the total number of iterations through which the data will be recycled in the ISOCLS clustering. The assigned value is based on user experience with similar data and applications. It will reduce machine time by allowing the user

ParameterDescription

to abort the process when it is apparent that the clusters have stabilized; that is, when insignificant changes appear in cluster means and standard deviations from one iteration to the next.

Upon completion of this process, means and covariance matrices will be generated for the cluster or clusters which would imply the existence of subclasses for the class corn.

2. Repeat the operation described in step 1 above for the class soybeans.
3. Repeat the operation described in step 1 above for the class wheat.
4. Generate detailed clustering reports and intercluster distance reports for steps 1, 2, and 3 above and hard copies for postanalysis review.

I.1.1.6 Area definition.-- The analyst will return to clustering initialization to cluster all the class "other" training fields collectively, utilizing the same parameters as in step 1 of section I.1.1.5. This will produce clusters and their associated statistics for other classes to be used in subsequent classification processing.

I.1.1.7 Classification.-- The analyst will return to pattern recognition to enter the classification.

I.1.1.8 Checkpoint/restart.-- The analyst will return to pattern recognition to generate a checkpoint tape of the previously produced statistics (means and covariance matrices)

using the image set identifier described in section I.1.1.1. This will preserve these statistics for utilization in the event of system failure and in subsequent nonlocal recognition runs. The analyst will then

1. Initiate the classification processor using all channels for all classes for the training and test fields defined in section I.1.1.3 and utilizing the statistics generated as described in sections I.1.1.4 and I.1.1.5.
2. Generate a classification summary report from the resulting classification and hard copies for post-processing review and historical reference.
3. Assign a color image of the classification for each segment with no thresholding: yellow to the corn classes, red to the soybean classes, green to the wheat classes, and white to all other classes. The displayed image should be examined on a training-field-by-training-field basis, and any observed anomalies should be recorded (for example, the erroneous classification of corn as soybeans). This log will be used for historical reference as required.
4. Generate, on microfiche for recording purposes, a classification character map with default symbols and no thresholding.
5. Classify all training fields using the statistics generated from the clustering runs, produce a classification summary report, and display a recognition map with no thresholding. The results should be examined on a field-by-field basis to determine the following.

- a. That each field has at least 75 percent assignment to its correct major class; that is, a corn training field must have at least 75 percent pixels assigned to a corn class.
- b. If condition a is not satisfied, that the field contains a contiguous area 50 percent or greater which satisfies condition a.

If neither condition is satisfied, the field should be deleted from the statistics for class K. If one of the conditions is satisfied, the field should be reassigned as a test field for class K.

6. Inform the Technical Advisory Team of all fields which do not satisfy the above conditions.
7. Enter statistics and regenerate statistics for the class K fields which do not satisfy step 5.a above.

I.1.1.9 Reinitialization.-- The analyst will return to the pattern recognition supervisor and reinitialize the process using the image set identifier as in section I.1.1.1.

I.1.1.10 Test field selection.-- The analyst will enter 20 sections as a test field via the keyboard and the LARS list of field boundary coordinates. Because the ERIPS is constrained to a 200-field maximum and it is possible that more than 200 fields will be defined, the 20 sections will be processed first. The test fields will then be processed in 200-field intervals in their sequential order on the LARS list. These steps will provide: the proportion classification performance vector, which results from classifying the 20 sections of the segment J; and the classification performance matrix from the test fields defined by LARS, which also lie in these 20 sections.

I.1.1.11 Classification of sections.-- The analyst will return to pattern recognition and will

1. Classify the 20 test sections using all channels for all classes and utilizing the statistics described in section I.1.1.8.
2. Generate a classification summary report with hard copies for the 20 sections with a 0.5 threshold value. This report will yield the proportions of corn, soybeans, wheat, and "other" for the 20 sections in segment J.
3. Perform the activities described in section I.1.1.8 for postanalysis review and historical reference.

I.1.1.12 Checkpoint tape.-- The analyst will return to pattern recognition and will generate a checkpoint tape of the test field definitions for the 20 sections of segment J for use in subsequent ERTS passes and for nonlocal recognition processing.

I.1.1.13 Subsequent processing of test fields.-- The analyst will return to the pattern recognition supervisor, reinitialize, and enter 200 test fields in their sequential order from the LARS list of boundary coordinates. These will be classified in the same manner as set out in section I.1.1.10 to produce the classification performance matrix for subsequent analyses of variance. The steps described in sections I.1.1.11 and I.1.1.12 will then be repeated for these test fields.

This procedure will be repeated for all remaining test fields in 200-field increments until no test fields remain to be processed.

I.1.1.14 Completion and signoff.-- When test field data are exhausted, the analyst will return to the application selection menu to "delog" and load reports and menus. Reports and menus for pattern recognition, loading and "delogging" will provide, for historical reference, a complete listing of all the processing operations and the results produced for this entire processing session. The analyst will sign off ERIPS and procure all generated hard copies and computer tapes.

I.1.2 Nonlocal Recognition Processing

The procedures described in this section will be utilized when required to perform nonlocal recognition on segment I using statistics generated from segment J.

I.1.2.1 Sign-on to ERIPS.-- The analyst will sign on to ERIPS and load the image data for segment I using the identification scheme described in section I.1.1.1.

I.1.2.2 Pattern recognition and image display.-- The analyst will enter pattern recognition and the image set identifier for training segment J and generate processing according to the procedures set out in sections I.1.1.1 through I.1.1.7.

I.1.2.3 Checkpoint/restart.-- The analyst will restart using the checkpoint tape as generated in section I.1.1.8 for training segment J. This will enter the required statistics (means and covariance matrices) for segment J into the ERIPS processor.

I.1.2.4 Report mode.-- The analyst will return to pattern recognition, generate a mean and standard deviation report from the checkpoint tape, and examine the tape to verify that the correct statistics are loaded.

I.1.2.5 Reinitialization.-- The analyst will return to the pattern recognition supervisor, enter the image set identifier for segment I, and restart using the checkpoint tape generated as in section I.1.1.12 for the 20 test sections of segment I.

I.1.2.6 Classification.-- The analyst will return to pattern recognition and classify the 20 test sections of segment I following the steps in section I.1.1.11.

I.1.2.7 Subsequent processing of test fields.-- The analyst will return to pattern recognition and repeat the procedures set out in section I.1.1.13 for the test fields in segment I, in increments of 200 fields per cycle, until test field data are exhausted.

I.1.2.8 Completion and signoff.-- The analyst will "delog" and sign off as described in section I.1.1.14.

I.2 M²S-EOD-SP1

All the procedures defined in this section relate to operations on the JSC Earth Resources Data Processing System implemented on the Univac 1100 series computers. Details of the specific subsystems may be obtained by referring to the following documents.

1. *The JSC ADP Data Handling Facilities Available to EOD Investigators*, EOD internal note, September 1973.
2. *User's Guide for the JSC Implemented Version of ACORN4*, to be published.
3. *Utilization of the JSC Implemented Version of Linear Combination of Features Selection for Classification*, EOD-TF7 internal memorandum, August 1973.
4. *Description and User's Guide for a Processing System for Airborne Multispectral Scanner Data*, MSC-01646, October 1970.

Utilizing this system affords the opportunity for using the improved capabilities of the University of Houston feature selection program and the associated modified LARSYS 3 classifier. Thus, to conserve limited ADP resources, the data sets received in the project which contain six or more multispectral bands will be processed on this system.

I.2.1 Local Recognition Processing

I.2.1.1 Activation of LARS terminal.-- Once the edited and reformatted tapes are received from LARS for segment J as defined in the Task Design Plan, section 5.0, the EOD LARS terminal will be activated to produce LARSYS 12 punched cards of the field boundaries defined by the LARS.

I.2.1.2 Grouping of LARSYS 12 cards.-- The LARSYS 12 cards will be grouped according to their respective class assignments as indicated in the following table.

| <u>Group</u> | <u>Description</u> |
|--------------|--------------------------------|
| 1 | Corn training fields |
| 2 | Soybean training fields |
| 3 | Wheat training fields |
| 4 | Other training fields |
| 5 | The 20 test sections |
| 6 | All the defined test fields |
| 7 | All other miscellaneous fields |

I.2.1.3 ISOCLS run deck.-- The analyst will prepare an ISOCLS run deck for clustering, as described in appendix C and in the document entitled *ISOCLS, Iterative Self-Organizing Clustering Program*, CO94, CPO202, October 1972. Four separate jobs will be stacked back to back according to the groups identified immediately above, as follows:

| <u>Job</u> | <u>Description</u> |
|------------|--|
| 1 | A clustering of the corn training fields using only the field boundary definition cards from group 1. |
| 2 | A clustering of the soybean training fields using only the field boundary definition cards from group 2. |
| 3 | A clustering of the wheat training fields using only the field boundary definition cards from group 3. |
| 4 | A clustering of the other training fields using only the field boundary definition cards from group 4. |

The above option applies here as in procedure I.1.1; that is, if the Technical Advisory Team determines that an

insufficient number of fields exist in segment J for a particular class to meet task objectives, it may recommend that the field definitions for that class be processed with the class "other."

The specific parameters to use for all channels are: STDMAX = 4.25 , DLMIN = 3.2 , NMIN = 100 . These parameters control the clustering process in the same manner as described in section I.1.1.5. The specific values chosen were based on empirical results from similar applications such as those discussed in *The JSC Clustering Program ISOCLS and its Applications*, LEC-0483, July 1973.

The clustering process is utilized in order to determine the unimodality of the classes of interest and to generate means and covariance matrices of the resulting clusters for subsequent feature selection and classification processing.

An ISOCLS run utilizing statistically punched cards should be submitted, also, for one iteration; ITMAY = 0 for groups 1 through 4 and for the test fields, group 6. A computer printout should be obtained for use in identifying field and class associations for both the training and the test fields.

I.2.1.4 Examination of line printer output.- Upon receipt of the clustering results, the analyst should examine and evaluate the output from the clustering routine in the following manner.

1. Each of the input training fields should be checked to verify that no human errors were made in field boundary definitions or class assignments.

2. The training fields should be checked to ascertain if any unique clusters were defined or broken in to distinct parts. For example, a wheatfield may be in a state of harvest, which could be apparent from the clustering process. These phenomena should be logged and reported to the Technical Advisory Team for further action.
3. All the test fields should be correlated with their respective subclasses. If all test fields are not so correlated, the class assignments on the LARSYS 12 cards referred to in section I.1.1.2 should be changed to reflect proper correlation.

(NOTE: Class assignments will be made on the basis of visual assessments of the cluster symbols assigned to each field. This is done to aid subsequent reviews of classification performances and otherwise will not affect the final results.)

4. Some of the subsequent ADP processors are limited to 20 classes. It is possible to generate statistics for more than 20 classes (clusters) from the ISOCLS runs. If this occurs, the following guidelines will be used to arrive at a final set of 20 classes.
 - a. The number of pixels in each cluster should be 10 times the number of classes to discriminate; for example, if the job is to discriminate 20 classes, then at least 200 pixels will be required for training. (NOTE: This rule should be followed regardless of the number of classes. Also, the clustering process has already established 100 as the minimum number of pixels allowed to define a unique cluster.)

- b. Each major class, that is, corn, soybeans, or wheat, should be limited to 12 subclasses. This would allow four clusters each to define the three major subclasses and eight for all "other." The chaining algorithm, along with the examination described in step 1 above, should be utilized to select the appropriate four subclasses. Clusters recommended by the chaining algorithm should be combined. If a major class still contains greater than 6 subclasses and more than 12 subclasses exist for the major crops, the chaining algorithm should be applied to the subclasses for "other." If more than 20 subclasses still exist, the analyst should retreat, iteration by iteration (the ISOCLS routine prints out the results of the clustering process after each iteration), until the number of clusters is reduced to 20.

I.2.1.5 Feature selection processor.— Once the final set of classes and their associated statistics (means and covariance matrices) have been defined, they will be used as input to the feature selection processor (see ref. 3 of section I.2). This processor was developed by the University of Houston. In general, it is a feature selection program that finds a linear transformation B of the measurements X such that the average transformed divergence is maximized over all pairs of classes of interest.

The required inputs for operation of the program and the values selected for this task are listed in the following table.

| <u>Parameter</u> | <u>Description</u> |
|-------------------------------|---|
| NN = . | The number of channels from which features are to be extracted; for example, 12 for the ERIM scanner M-7. |
| ICLSS = (). | The number of classes to be discriminated as determined in section I.1.1.4. |
| IOUT = 4. | A code to indicate that statistics will be read in from punched cards. |
| KDIM = 5. | The number of linear combinations that are to be found by the program. |
| KBAR(I) I = 1 , KDIM × NN. | The initial guess for the B-matrix. The values to be used for the M ² S scanner are: XBAR(4) = 1.DO XBAR(18) = 1.DO XBAR(31) = 1.DO XBAR(43) = 1.DO XBAR(55) = 1.DO |

The above selection of values will cause channels 4, 7, 9, 10, and 11 to be chosen as the initial linear combination. An analytical determination will be made as to which group of five features and its associated B-matrix will be used to transform the observations for maximizing the separability between the features of interest. Based upon this determination, the program will recycle until stability is reached. The B-matrix will be punched on cards for input to the classification processor. (An upgraded version of the feature selection processor will include automatic punching of the B-matrix cards.)

I.2.1.6 Classification processor.- The output from the feature selection processor will be input to the classification processor. The B-matrix generated by the feature selection processor will be punched on cards with a 4E20.3 format. All other cards in the deck setup, with the exception of the features card, will be the same as for the original version of LARSYSAA on the Univac 1108 (described in *Description and User's Guide for a Processor System for Airborne Multispectral Scanner Data*, MSC-01646, October 1970, and *Modifications to the 1108 Version of LARSYSAA*, Technical Memorandum 3012, February 1973). The features card is replaced by:

Columns 1 - 7

EXTRACT

Column 11

X

where X = the number of linear combinations found by the feature selection routine . In this task, X = 5 .

The classification run will include all defined fields as identified in section I.2.1.2; that is, the LARSYS 12 cards for group 1 will be processed first, then group 2, and continuing through group 7.

Groups 1 through 4 will provide classification performance summaries for the training fields; group 5 will provide the classification proportion vectors; and group 6 will provide the classification performance matrices required for subsequent analyses of variance. The classification results should be submitted to the display processor using a threshold of 8.35. This value is the chi-square equivalent for 99.5 percent probability of correct classification using five multispectral channels. The LARSYSAA will then generate these classification vectors and matrices.

I.2.2 Nonlocal Recognition Processing

I.2.2.1 Field definitions. - The field definitions for segment K to be classified will be retrieved as generated in section I.2.1.3.

I.2.2.2 Statistics. - The statistics (B-matrix, means and covariance matrices) of the segment J to be used for training will be retrieved as generated in section I.2.1.5.

I.2.2.3 Classification. - The statistical and field definition data will be submitted to a LARSYSAA classification run as described in section I.2.1.6, and the required classification performance matrices and classification proportion vectors will be produced.

I.3 M^2S -EOD-SP2

The procedure for the analysis of M^2S MSS channels which are compatible with ERTS-1 MSS bands (M^2S bands 4, 6, 8, and 10) will be the same as those described for ERTS-EOD-SP1, section I.1, with the following exceptions.

Section I.1.1.2, steps 1 and 3, will be changed to read:

1. Generate a gray-scale image of segment J from a histogram of the first 50 lines of M^2S band 4.
3. Repeat steps 1 and 2 for M^2S bands 6, 8, and 10.

The first sentence of section I.1.1.5, step 1, should be changed to read:

Initiate the clustering processor for the class corn using channels 4, 6, 8, and 10. STDMAX = 4.25 , DLMIN = 3.0 , NMIN = 100 , and ITMAX = 5 .

Section I.1.1.8, step 1, should be changed to read:

1. Initiate the classification processor using channels 4, 6, 8, and 10 for all the training and test fields defined in section I.1.1.3 and utilizing the statistics described in sections I.1.1.4 and I.1.1.5.

Section I.1.1.11, step 1, should be changed to read:

1. Classify the 20 test sections using channels 4, 6, 8, and 10 for all classes and utilizing the statistics described in section I.1.1.8.

I.4 M²S-EOD-SP3

The procedures for the analysis of M²S MSS channels which are compatible with projected ERTS-B bands (M²S bands 4, 6, 8, 10, and 11) will be the same as those for M²S-EOD-SP2, as described in section I.3, with the exception that channel 11 will be added wherever channel assignments are required.

I.5 M²S-EOD-PSP1

The procedures for this analysis will be the same as those described for M²S-EOD-SP1 in section I.2, with the following exception: The digital M²S data will undergo radiometric preprocessing prior to the initialization of standard processing as described below:

(To be supplied)

I.6 ERTS-EOD-MSP1

The procedures for the processing of multitemporal ERTS-1 data assume that the data passes have been registered prior to any processing. Otherwise, the procedures will be the same as those described for M²S-EOD-SP1 in section I.2, with the following exceptions.

The clustering parameters in section I.2.1.3 should be changed to: STDMAX = 3.2 , NMIN = 30 . All other parameters remain the same.

The last parameter in section I.2.1.5 should be changed to:

| <u>Parameter</u> | <u>Description</u> |
|-----------------------------------|---|
| XBAR(I) I = 1 , ..., B-matrix. | The values to be used for the two-pass ERTS-1 scanner data sets are: XBAR(3) = 1.DO XBAR(12) = 1.DO XBAR(22) = 1.DO XBAR(31) = 1.DO XBAR(40) = 1.DO |

The above selection of values will cause channels 3 and 4 of pass 1 and channels 2, 3, and 4 of pass 2 to be chosen as the initial linear combinations. An analytical determination will be made as to which group of five features and its associated B-matrix will be used to transform the observations for maximizing the separability between the features of interest. Based upon this determination, the program will recycle until stability is reached. The B-matrix will be punched on cards for input to the classification processor.

I.7 M-7-EOD-SP1

The procedures for the analysis of M-7 MSS data will be the same as those described for the M²S-EOD-SP1 in section I.2.

I.8 M-7-EOD-PSP1

The procedures for this analysis will be the same as those described for M²S-EOD-PSP1 in section I.5.

I.9 CONTINGENCY PROCEDURES

These contingency procedures have been devised to ensure the continuation of ADP activities in the event of failure of the ERIPS or Univac 1100 systems. "Failure" is defined to occur when any operational subsystem (in the opinion of the ADP team leader) is not performing to advertised specifications or is temporarily or permanently inaccessible, because of scheduling or implementation delays.

Redundant capabilities existing in the ERIPS and Univac 1100 series systems are currently defined for utilization by the CITARS task. Therefore, the description and utilization of contingency procedures should not significantly impact analyst activities or the associated output performances.

Contingency procedures will be described only for those major subsystems where utilization is a major factor in the degree of success or performance of the system. These subsystems are:

1. Clustering/statistics
2. Feature selection
3. Classification

I.9.1 Clustering/Statistics

It is anticipated that the only failures in clustering activities will be associated with the ERIPS. The ERIPS clustering processor has not been tested for performance in terms of an application. In addition, operational discrepancies have occurred in recent utilization of this subsystem. These anomalies have been documented and submitted for implementation. If the utilization of the ERIPS clustering application remains questionable at the time it is required to process a particular data set, the following procedure will be followed.

I.9.1.1 Clustering defined training fields and generating nonsupervised classification printout.- The procedures defined for M²S-EOD-SP1, sections I.2.1.1 through I.2.1.4,

will be utilized for clustering the defined training fields and for generating a nonsupervised classification printout of these training and test fields.

All specified parameters will remain the same, with the following exceptions for ERTS data: $STD_{MAX} = 3.5$, and $N_{MIN} = 30$.

I.9.1.2 Listing field and class assignments.- A list of field and class assignments for both the training and test fields will be produced utilizing the clustering procedures set out in section I.1.1.4. The training field class assignments are to be based on the following:

1. Fields containing 75 percent or greater pixel assignments to a subclass K will be designated as training fields for class K.
2. Fields containing less than 75 percent assignment to a single subclass but which contain a contiguous area of 50 percent or greater having 90 percent assignment to a single class P, after informing the Technical Advisory Team, will be assigned as follows:
 - a. The 50-percent area will be assigned to class P.
 - b. The remaining area will be assigned by condition 1 above or condition 3 below.
3. Training fields which are heterogeneous, that is, a random combination of class/subclass mixtures, will be noted as test fields and brought to the attention of the Technical Advisory Team.

The final list of training and test field class assignments will be submitted to ERIPS processing as in section I.1 (ERTS-EOD-SPl), with the following exceptions.

Steps 1 and 2 of section I.1.1.3 will be changed to read:

1. Enter all the training fields from the final list of training and test field class assignments via the keyboard. Appropriate class assignments should be input for each field; for example, corn A, corn B, soybeans, wheat 1, wheat 2, trees, water, and so forth.
2. Enter each 8- by 32-kilometer segment as a test field via the keyboard.

The steps described in sections I.1.1.5 and I.1.1.6 will be skipped.

Section I.1.1.13 will be changed to show that test fields will be entered from the final list of training and test field class assignments in increments of 200 until test field data are exhausted. Also, all test fields for a specific class must be entered before data from another class are submitted.

Procedures for completion and signoff will be as set out in section I.1.1.14.

I.9.2 Feature Selection

Feature selection must have a contingency procedure because of the possibility of data sets currently assigned

for processing on the Univac 1100 being reassigned to the ERIPS. Any of these data sets containing greater than six channels of MSS data will be submitted to the ERIPS divergence routing (see the *ERIPS Requirements Document*, PHO-TR514, March 1973, and the *ERIPS User's Guide*, Volume 1, revised July 1973).

The procedures for utilizing the ERIPS divergence routine will be the same as those described in section I.1 (ERTS-EOD-SPI), with the following exceptions.

Section I.1.1.7, Divergence, will be changed to read:

The analyst will return to pattern recognition and

1. Initiate the divergence processor. The best five of the available channels (channels which are known *a priori* to be unusable may be excluded from divergence processing) for all classes will be requested, and channel selection will be based on D(AVE), the divergence average. All other options will be defaulted.
2. Produce a divergence display report, with hard-copies for historical reference, based on a ranking with respect to D(AVE).

Step 1 of section I.1.1.8 will be changed to read:

1. Initiate the classification processor using the best set of channels selected by D(AVE) for all classes for the training and test fields defined in section I.1.1.3 and utilizing the statistics described in sections I.1.1.4 and I.1.1.5.

Step 1 of section I.1.1.11 will be changed to read:

1. Classify the 20 test sections using the best set of channels selected by D (AVE) for all classes and utilizing the statistics described in section I.1.1.8.

I.9.3 Classification

The classification processors for both ERIPS and the Univac 1100 series facilities have been described previously (see sections I.1 and I.2). It is unlikely that the classification processors for these systems would be required for utilization independently of the statistics on the feature selection processor; that is, the system which generates the statistics for a data set normally will perform the follow-on classification. Thus, the contingency procedures described in sections I.9.1 and I.9.2 for clustering/statistics and feature selection, respectively, in effect denote contingency classification measures. The only exception is that for the ERIPS an additional classification (and feature selection, also, if required) processor is available. This system is the LARSYS 12 on the CYBER 73 computer. Access to the CYBER is available only through the ERIPS and its Batch System Interface (BSI) subsystem. The only means of obtaining hard-copy output from the actual ERIPS is through the peripheral hard copies of the conversational CRT, and it is subject to mechanical failure. Thus, it is desirable to maintain an alternate means for obtaining hard-copy output of the classification performance summaries, statistics reports, and other pertinent data. The use of the BSI provides this alternative.

The procedures for utilizing the BSI are the same as those described in section I.1 (ERTS-EOD-SP1), with the following exceptions.

Section I.1.1.8, Batch Interface, will be changed to read:

The analyst will return to pattern recognition, enter batch interface, and

1. Select a classification run on the BSI. (Although it is not recommended, divergence also may be requested here, if required and not completed previously according to the procedures described in section I.9.2.)
2. Assure that all channels (or those selected from previous feature selection activity) are used and that all classes, as previously identified, are classified for all of the training fields.

The generated BSI tapes will be run offline, and the necessary output will be produced on a computer printout as described in *CYBER 73 LARSYS Software User's Guide*, Control Data Corporation, October 1972.

Section I.1.1.11, Classification of sections, will be changed to read:

The analyst will return to pattern recognition, enter batch interface, and

1. Select a classification run on the BSI. (Although it is not recommended, divergence also may be requested here, if required and not completed

previously according to the procedures described in section I.9.2.)

2. Assure that all channels (or those selected from previous feature selection activity) are used and that all classes, as previously identified, are classified for all of the test fields.

Section I.1.1.13, Subsequent processing of test fields, will be changed to read:

The analyst will return to the pattern recognition supervisor, reinitialize, and select a classification run on the BSI. These test fields will be classified in the same manner as set out in section I.1.1.10 to produce the classification performance matrix for subsequent analyses of variance. The steps described in sections I.1.1.11 and I.1.1.12 will then be repeated for these test fields.

This procedure will be repeated until all data from BSI test field classification runs have been entered. The generated BSI tapes will be run offline, and the necessary output will be produced on a computer print-out as described in the *CYBER 73 LARSYS Software User's Guide*.

Section I.1.1.14, Completion and signoff, will be changed to read:

When BSI test field classification data are exhausted, the analyst will return to the application selection menu to "delog" and load reports and menus. Reports and menus for pattern recognition loading and

"delogging" will provide, for historical reference, a complete listing of all the processing operations and the results produced for this entire processing session. The analyst will sign off ERIPS and procure all generated hard copies and computer tapes.

APPENDIX J
LARS DATA ANALYSIS PROCEDURES

APPENDIX J

LARS DATA ANALYSIS PROCEDURES

J.1 INTRODUCTION

The analysis techniques to be used by Purdue/LARS for the various sensor platform/data processing technique combinations differ only in detail. Therefore, it will be convenient first to provide a general description and rationale for the procedures and then to indicate where the variations will occur. A step-by-step description of the analysis procedures as they will be carried out by the data analysts will follow.

The LARSYS 3 system will be employed throughout. Pertinent theoretical background may be found in *Pattern Recognition: A Basis for Remote Sensing Data Analysis*, by P. H. Swain, LARS Information Note 111572. Details of the algorithm implementation are contained in the *LARSYS User's Manual* (three volumes), T. L. Phillips, ed.

J.2 DATA ANALYSIS PROCEDURES SPECIFICATION

J.2.1 General Procedures and Rationale

J.2.1.1 Preparation.- The first job of the data analyst is to obtain the run number corresponding to the data set to be analyzed and to verify the identify of that data set. Copies of all boundary definition cards, including those for training fields, pilot fields, test fields, pilot sections, and test sections should be obtained. The analyst shall

make a copy of the run for future use in order to minimize wear on the library tape and to improve his accessibility to the data set.

J.2.1.2 Data quality check.- Although the data will have been screened during the preprocessing operations, the analyst must be alert to recognize any serious problems in the data set, which may have been missed in the screening process. The analyst will look for evidence of data dropout, instrument noise problems, and clouds that may obscure the training fields. If problems that have not been detected previously in the data screening process are encountered, they should be called to the attention of the data analysis supervisor, who, in turn, will consult with the Technical Advisory Team as to what action, if any, should be taken.

J.2.1.3 Class definition and refinement.- For the purposes of this experiment, four major classes will be defined: corn, soybeans, wheat (for selected missions), and all other ground covers considered together as a single class. Where spectral variability within a class is so great as to result in a multimodal probability distribution for that class, these major classes will be subdivided into subclasses.

To isolate subclasses of the major ground-cover classes, cluster processing will be applied to the training fields as follows.

| <u>Major class</u> | <u>Number of clusters requested</u> |
|-----------------------|---|
| Corn | Five |
| Soybeans | Five |
| Wheat | Five (if applicable) |
| "Other": Agricultural | Ten |
| Nonagricultural | Three for each identifiable ground-cover type |

If, for example, the nonagricultural "other" consists of water, woods, and farmstead, then nine clusters should be requested in processing this class. Exception: In no case should the number of clusters requested exceed one-tenth the number of points in the training fields, divided by the anticipated number of channels to be used later in the classification step. This restriction is made to be consistent with a later requirement -- that each class or subclass to be used in classification be represented by at least a number of points equal to 10 times the number of channels used for the classification.

All available spectral channels will be used for clustering the ERTS data. The channels to be used for clustering aircraft data will consist of a representative selection of the available channels. (When the characteristics of the sensor systems are available to the LARS Analysis Team management, they will be specified explicitly to the analyst.)

The cluster processor will be used directly to punch a set of statistics corresponding to each of the resulting clusters. The analyst will interpret the separability

information produced by the program and merge clusters and cluster groups according to the following procedure:

Assuming n clusters, let d_{ij} ($i = 1, 2, \dots, n$; $j = 1, 2, \dots, n$) be the pairwise "quotients" (Swain-Fu distances) between the clusters. Let C_i be the cluster group (C-group) to which cluster i belongs.

1. Initially assign each cluster to its own cluster group, C_1, C_2, \dots, C_n .
2. Order and list the values of d_{ij} from smallest to largest and work through the list as follows.
3. If $d_{xy} > 0.75$, stop (merging is complete).
4. If cluster x and cluster y belong to the same C-group ($C_x = C_y$), proceed to the next value of d_{xy} (returning to step 2).
5. Compute the average distance \bar{d}_{xu} between C_x and each other C-group $C_u \neq C_x$ for which $d_{ab} \leq 0.75$ for all a in C_x and b in C_u (the average distance between C-groups is defined as the average of all pairwise distances between points in the different C-groups). Similarly, compute the average distance \bar{d}_{uy} between C_y and each other C-group $C_u \neq C_x$ for which $d_{ab} \leq 0.75$ for all a in C_u and b in C_y .
 - a. If $\bar{d}_{xy} \leq$ all of the intergroup distances so computed, then assign both C_x and C_y to the same C-group; that is, $C_x = C_y = \text{MIN}(C_x, C_y)$. Select the next d_{xy} (returning to step 2).
 - b. Otherwise, simply select the next d_{xy} (returning to step 2).

This procedure will provide a systematic means for interpreting the separability information, minimizing the total number of subclasses produced, and at the same time ensuring that multimodal class distributions are avoided. (To avoid analyst error, the procedure will be implemented as part of the clustering algorithm.) The threshold value of 0.75 has been selected because of extensive past experience which indicates that this is an appropriate value to use for avoiding multimodal distributions.

The merged cluster groups will constitute the classes for classification purposes. Exception: The analyst will delete from further consideration any cluster group which contains fewer points than 10 times the number of channels to be used for classification. (This would be too few points for estimation of subclass statistics.)

Each execution of the clustering program will produce a deck containing the statistical characterizations of the subclasses of one of the major classes. Thus, four or five such decks (depending on whether wheat is treated as an identifiable class) will be produced for each analysis. These decks will be merged into a single statistics deck by means of a computer program.

J.2.1.4 Spectral band selection (aircraft data only).-
If more than four spectral bands are available for analysis, the separability processor will determine how many and which spectral bands will be used. Based on average transformed divergence, the best combinations of four, five, and six bands will be determined. A combination containing a larger number of bands will be used only if the average

transformed divergence for this combination is at least 5 percent greater than for a smaller number of bands. This criterion is based on the observation that, unless at least 5 percent improvement in performance is obtainable, the cost in computer time when more spectral bands are used is not warranted.

All class combinations not requiring discrimination (for example, subclasses within each major class) will be given zero weight in the separability processing.

J.2.1.5 Classification.- Each data set will be analyzed initially, using two versions of the maximum likelihood decision rule. After an evaluation has been made of their relative performances, the use of one of these rules will be discontinued.

The first rule is the maximum likelihood classification rule assuming equal prior probabilities for all classes. This has been in common usage for remote sensing data analysis for some time.

The second rule will use class weights in proportion to the class prior probabilities. This approach is more nearly optimal, given that the Bayesian error criterion (minimum expected error) is preferred. The weights will be computed as follows. If n_{ij}^{train} = the number of training field points in subclass i of class j , n_j^{train} = the total number of training field points in class j , and α_j = the proportion of the data points in the pilot sections belonging to class j , then W_{ij} , the weight assigned to the i th cluster of the j th class, is given by the following equation.

$$W_{ij} = \frac{n_{ij}^{\text{train}}}{n_j^{\text{train}}} \cdot \alpha_j \quad (\text{J-1})$$

In each case, the classification results will be stored on magnetic tape for future reference.

J.2.1.6 Display and tabulation of results.- The results of the classification will be displayed using a discriminant threshold of 0.1 percent. This light threshold should eliminate only the data points that vary to a large extent from the major class characterizations. Threshold points will be counted in the category "other."

The computer program will tabulate results in both printed and punched card form for (1) the training fields as supplied to the analyst, (2) the pilot fields, (3) the test fields, (4) the pilot sections, and (5) the test sections.

J.3 STEP-BY-STEP INSTRUCTIONS FOR THE DATA ANALYST

The MSS data analysis procedures specified below are designed to be as mechanical as possible. In effect, they short-circuit analyst judgment to maximize repeatability. The data analyst must conform rigidly to the specifications without reducing the level of care and attention applied to his analysis work. Some points in the process are quite complex, and errors can be made if sufficient care is not taken. Past experience with LARSYS has shown that good judgment on the part of the analyst will enable him to detect any problems or inconsistencies which may develop as the analysis progresses. If any problems or indications

of problems or inconsistencies are detected, the analyst should halt his work and consult the data analysis supervisor. The analyst should not alter the procedure in any way without prior approval in writing from the data analysis supervisor.

J.3.1 ERTS-LARS-SP1

J.3.1.1 Preparation.-- The data analysis supervisor will notify the analyst when a data set corresponding to the requested segment or segments becomes available. The analyst should

1. Obtain the run number and field description cards (training fields, pilot fields, test fields, pilot sections, and test sections) for the data set.
2. Use the *DUPLICATERUN processing function to make a copy of the data set on a personal tape for easy access and to minimize wear on the library tape.

J.3.1.2 Data quality check.-- The data will have been screened twice -- once as part of the reformatting process and again when the field boundaries were edited to account for clouds and other cultural and natural phenomena. The data analyst should be aware of any unusual conditions detected and alert for any which may not have been detected in the screening processes. The analyst can ascertain such conditions by

1. Information from the data analysis supervisor concerning serious problems in the data; for example, bad channels which should not be used. (This information should be provided when the analyst is notified that the requested data are available.)

2. Checking the data log records and noting any problems which may be recorded.
3. Using the digital display or making gray-scale printouts of the entire run on all channels to display all of the boundaries supplied for the run. The following deck setup may be used:

```
*IMAGEDISPLAY or *PICTUREPRINT
DISPLAY RUN(x) (x = run to be viewed)
CHANNELS 1,2,3,4
BOUNDARY STORE
DATA (deck containing training, pilot, and test fields
      and other available boundaries)
END
```

The data analyst should look for evidence of noisy or missing data, clouds which obscure all or portions of the areas enclosed by the supplied boundaries, and other conditions which may be unusual.

Important: Unless the data analyst has been notified explicitly to the contrary by the data analysis supervisor, he shall consider all of the data (the entire area and all channels) available for analysis. If any conditions which warrant further consideration are detected, these conditions should be called to the attention of the data analysis supervisor. The analysis should halt until a decision is returned to the analyst as to what action should be taken.

J.3.1.3 Class definition and refinement.- Four ground-cover types will be discriminated: corn, soybeans, wheat, and "other." However, "other" will be subdivided into agricultural and nonagricultural. In many cases, wheat may be

omitted as an identifiable class. Training fields will be supplied for each of the categories to be discriminated.

The CLUSTER processing function should be applied separately to each major class to detect and eliminate multimodal distributions. The number of clusters requested should be specified as follows:

| <u>Major class</u> | <u>Number of clusters requested</u> |
|-----------------------|--------------------------------------|
| Corn | Five |
| Soybeans | Five |
| Wheat | Five (if applicable) |
| "Other": Agricultural | Ten |
| Nonagricultural | Three for each identifiable subclass |

If, for example, the nonagricultural other class consists of water, trees, and airport, then nine clusters should be requested to process this category. Exception: In order to have a sufficient number of points in each subclass to be derived from the clustering, the number of clusters requested should be divided into the number of data points available for clustering; if the result is less than 40 (that is, 10 times the expected number of channels to be used for classification), the number of requested clusters should be reduced.

All available spectral channels should be used for clustering, and a punched deck of statistics should be requested. One deck of statistics will be produced by each cluster analysis, and these decks will be merged later.

The following deck setup is appropriate:

```
*CLUSTER (for corn)
OPTIONS MAXCLS(x) (x = number of clusters, as specified
                    above, usually five)
PUNCH STATS
CHANNELS 1,2,3,4
DATA (cards for corn training fields)
END.
*CLUSTER
OPTIONS MAXCLAS(x) (for soybeans)
:
(Run will be repeated for all classes)
```

The cluster processor will produce a cluster merge table based on a quotient threshold of 0.75. Any cluster group containing fewer than 40 points (10 times the number of channels to be used for classification) should be deleted from further analysis. The remaining cluster groups will be used as classes for the purpose of classifying the data.

The MERGESTATISTICS program will combine the statistics decks produced by the multiple executions of the CLUSTER processor. The following deck setup is appropriate:

```
*MERGESTATISTICS
CLASSES DELETE(1/a,b,.../), DELETE... (specific classes to
                                         be deleted)
DATA (statistics decks punched by CLUSTER)
END
```

The statistics deck output by this run will be used for further analyses.

J.3.1.4 Spectral band selection.-- All available ERTS channels will be used for classification. No band selection, aside from deleting bad channels specified by the data analysis supervisor, will be required.

J.3.1.5 Classification.-- The CLASSIFYPOINTS processing function should be used to classify the segment, with all available channels and the set of subclasses determined in previous steps. The results should be stored on tape for further analysis. An appropriate deck setup is:

*CLASSIFYPOINTS

RESULTS TAPE(t), FILE(f) (the analyst's tape, next available file)

CLASSES... (cluster groups to be merged based on the cluster merge table)

CARDS READSTATS

CHANNELS 1,2,3,4 (all available channels)

DATA (statistics deck produced by MERGESTATISTICS)

DATA (coordinates, including run, lines, and columns, of the area to be classified)

END

J.3.1.6 Display and tabulation of results.-- Classification results must be tabulated for five distinct sets of field boundaries which have been supplied to the analyst: (1) the fields available for training the classifier, (2) the pilot fields, (3) the test fields, (4) the pilot sections, and (5) the test sections. Therefore, five passes through the PRINTRESULTS processing function will be required, in the order specified above, so the results summary punched on cards by the program will be properly organized. Training field boundaries will be handled in the same manner as test fields are normally treated.

A classification map will be generated for historical purposes on the first pass. On all passes, the classes must be grouped as corn, soybeans, wheat (if applicable), and "other," in that order, specifying a threshold of 0.1 percent. An appropriate deck setup is:

```
*PRINTRESULTS (first pass)
RESULTS TAPE(t), FILE(f)
PRINT OUTLINE(TEST), TEST(F,C)
SYMBOLS C,C,...,S,S,...,W,W,...,-,-,...
THRESHOLDS n*0.1 (n = number of classes)
GROUP CORN(1/C1,C2,.../)
GROUP SOYBEANS(2/d1,d2,.../)
GROUP WHEAT(3/e1,e2,.../)} (if wheat is identified; other-
GROUP OTHER(4/f1,f2,.../)} wise, group "other" will be
                           designated 3.)
DATA (deck of training field boundaries as supplied, with
      test cards added)
END

*PRINTRESULTS (second pass)
RESULTS TAPE(t), FILE(f)
PRINT MAPS(O), TEST(F,C)
THRESHOLD }
GROUP      } (same as previous pass)
:          }
:          }

DATA (deck of pilot field boundaries)
END

*PRINTRESULTS (third pass)
RESULTS TAPE(t), FILE(f)
:
:
```

(Run will be repeated for test fields, pilot sections, and test sections.)

The classification maps, tables, and punched results summaries should be submitted to the data analysis supervisor.

J.3.2 ERTS-LARS-SP2

The procedures for ERTS-LARS-SP2 will be the same as ERTS-LARS-SP1 (section J.1.3), except that the instructions set out in section J.1.3.5, Classification, will be changed to read:

The CLASSIFYPOINTS processing function should be used to classify the segment, with all available channels and the set of subclasses determined in the preceding steps.

Subclass weights will be computed as described below and supplied to the classifier. The weight for the i th subclass of the j th class is given by

$$W_{ij} = \frac{n_{ij}^{\text{train}}}{n_j^{\text{train}}} \cdot \alpha_j \quad (\text{J-2})$$

where: n_{ij}^{train} = the number of training data points in the i th subclass of the j th class (obtained from the CLUSTER function); n_j^{train} = the total number of training data points in the j th class (see CLUSTER results); and α_j = the fraction of the pilot data belonging to class j (supplied by the data analysis supervisor).

As a check, the sum of all the computed weights should be 1.0. The results should be stored on magnetic tape for further analysis.

An appropriate deck setup is:

```
*CLASSIFYPOINTS
RESULTS TAPE(t), FILE(f) (data analyst's tape, next
                           available file)
CLASSES... (cluster groups to be merged based on the
            cluster merge table)
WEIGHTS  $W_{11}, W_{21}, \dots$  (computed subclass weights)
CARD READSTATS
CHANNELS 1,2,3,4 (all available channels)
DATA (statistics deck produced by MERGESTATISTICS)
DATA (coordinates, including run, lines, and columns,
      of the area to be classified)
END
```

J.3.3 Aircraft-LARS-SP1/SP2

The procedures for aircraft-LARS-SP1 and -SP2 are the same as ERTS-LARS-SP1 and -SP2, respectively, except for modifications to the following sections.

J.3.1.2 Data quality check.- Alternating channels rather than all channels should be viewed. The CHANNELS card will read: CHANNELS 1,3,5, \dots .

J.3.1.3 Class definition and refinement.- Instead of using all available channels for clustering, a representative set of channels will be used (to be specified by the data analysis supervisor when additional information is available).

J.3.1.4 Spectral band selection.- A subset of the available aircraft scanner channels will be used for classification. The SEPARABILITY processing function should be used to determine the best combinations of four,

five, and six channels, based on average transformed divergence. (Do not use the SORT option, which ranks according to minimum, pairwise, transformed divergence.)

All class combinations not required to be discriminated (for example, all subclasses of a major class) should be given a zero weight. An appropriate deck setup is:

```
*SEPARABILITY
COMBINATIONS 4,5,6
SYMBOLS A,B,C,...
WEIGHTS... (zero weights for appropriate class pairs)
CLASSES... (cluster group to be merged based on the
              cluster merge table)
CARDS READSTATS
PRINT BEST(5)
CHANNELS 1,2,... (omitting unacceptable channels)
DATA (statistics deck produced by the MERGESTATISTICS
      program)
END
```

Only the top-ranked channel combinations of four, five, and six channels will be considered for use. The smaller number of channels should be utilized, unless the average transformed divergence for a larger number of channels is at least 5 percent greater than for the smaller number.

J.3.1.5 Classification.- The spectral channels selected by the SEPARABILITY processor should be used.

APPENDIX K
ERIM DATA PROCESSING AND ANALYSIS PROCEDURES

APPENDIX KERIM DATA PROCESSING AND ANALYSIS PROCEDURES

A stated goal of the CITARS project is to access the crop identification capabilities of existing remote sensor data processing technology and to document these efforts in such a manner as to eliminate the need for judgment on the part of the data analyst. The techniques to be assessed do not include certain advanced methods which are in various stages of development at ERIM.

Research at ERIM has emphasized the solving of certain problems, the result of which will lead to the development of operational remote sensor survey systems for large areas. These key problems include

1. Shortening the throughput rate of recognition processors
2. Extending signatures from training areas to other geographic locations and to areas under other observation conditions
3. Correcting misclassifications caused by the relatively large size of the spatial resolution element of data from satellite sensors.

The procedures described here for use on the CITARS project reflect those concerns. For example, when compared to the more conventional quadratic rule, the linear classification rule to be applied has shown comparable accuracy in tests and reduces the amount of digital computer time required for classification. Also, the outlined training procedure uses a minimum number of signatures, which also reduces computer time.

Preprocessing for signature extension is an important part of the tasks to be performed at the ERIM. Of the several different techniques that have been developed and are under investigation at the ERIM, only the most straightforward have been specified for use on the project. To solve the problem of classification inaccuracies over large areas that include field boundaries and nonagricultural materials, ERIM is using its technique for estimating proportions of unresolved objects. This technique, however, is not part of the CITARS project.

K.1 ERTS MSS DATA

K.1.1 Reformatting of the Data

The ERTS-1 MSS data for each test segment will be forwarded by LARS to the ERIM on nine-track, 315 bits per centimeter tapes in the channel-oriented LARSYS 3 format. These eight-bit data will be converted to the pixel-oriented, nine-bit ERIM format and placed on seven-track tapes.

K.1.2 Verification of Data Quality

This preliminary data quality check is intended to monitor the overall data quality so that any problems which appear can be corrected and the affected areas can be deleted before subsequent processing ensues. Problems which become apparent at this stage would be typical of the entire scene. Differences in the detector calibrations or errors in reformatting the data tapes are examples. The ERTS investigations at the ERIM, where specific problems have precluded the use of data from certain detectors or bands in recognition processing, have indicated the need for such tests. System

changes can and do occur; thus, the data analyst must continually check for them and be alert to changes, including types not previously observed.

The data quality tests are not oriented towards finding localized problems such as inhomogeneous fields, cloud cover over the 256-hectare (square-mile) test sections, or inaccuracies in field delineations, all of which are to be checked by other steps in the procedures. Accordingly, the tests will be applied over the entire area of the rectangle enclosing the test segment, both as a convenience in running the tests and in computing an average over this larger area. As a result, the effects of clouds, lakes, urban areas, and so forth on the histograms and statistics will average out in a similar manner for all detectors.

The steps for verifying data quality are set out below.

K.1.2.1 Generating gray maps for all channels.-

Four digital maps will be generated for each segment, one for each of the four channels. Each will cover all lines and points on the data tape, using the MAP program with its standard gray-tone darkness symbols for nine levels. The signal levels assigned to each of the nine gray-map levels will be determined separately for each channel. By using the MAP program's automatic level-set option, the levels will be based on a sample of points throughout the entire area of the rectangle enclosing each test segment. This can be accomplished by using the following settings when running the MAP program for each channel.

LMODE=2

NLEVEL=9

SSA=1,0,1,1,0,1

K.1.2.2 Examining gray maps.- The gray maps generated in the previous step will be examined for evidence of striping, banding, or signal breakup. Any such evidence will be considered further under the step described in section K.1.2.6.

K.1.2.3 Generating histograms, means, and standard deviations of data from each detector.- The STAT program will be run over the entire area of the rectangle, enclosing each test segment separately for each detector, with the option NOEDIT=\$ON\$. Each of the six possible sets that contain every sixth scan line of data will be specified as follows:

NSA=n,0,6,1,0,1

where n = (the first...the sixth scan line in the rectangle). This will generate 24 histograms (giving the number of data pixels having each signal level), one for each of the six detectors in each of the four channels. The corresponding 24 signal means and standard deviations will also be computed in the process.

K.1.2.4 Computing and testing the variances of detector means.- The data means generated above will be compared quantitatively with the six detectors in each channel. As a standard for comparison, a combined mean (and a standard deviation about that mean) will be determined for each combination of five detectors. A two-sided t-test with a (0.95) confidence level (NOTE: Values underlined within parentheses throughout these procedures are parameters which are subject to change as experience is gained on the project. All final data will be processed uniformly.)

will be applied to the mean for each remaining detector. Any time the mean of a detector is rejected, the procedure will be repeated with one less detector.

More specifically, $\left[C_j^i \right]_j^6 = 1$ will denote the collection of all combinations of six channel i detectors taken five at a time. For example, C_1^i might represent $(D_1^i, D_2^i, D_3^i, D_4^i, D_5^i)$ and so on, where D_k^i denotes the k th detector for channel i .

Let R_j^i denote the ensemble of five mean signal values over the segment, measured by C_j^i , a particular combination of five detectors. Using the mean values which have been calculated in section K.1.2.3, the following will be computed.

1. For each ensemble R_j^i , the mean μ_j^i and the standard deviation σ_j^i will be computed.
2. For each C_j^i in channel i ,

$$\left| \mu_j^i - \hat{\mu}_j^i \right| = \Delta_j^i \quad (K-1)$$

where $\hat{\mu}_j^i$ is the previously calculated mean of data from the detector not included in C_j^i .

3. If $\Delta_j^i > (2.57) \sigma_j^i$, the data from the detector will be rejected.
4. If a detector mean fails the test, this procedure will be repeated for the remaining N detectors with

$j = N$ and a rejection criterion, $\Delta_j^i > \lambda \sigma_s^i$, where λ is the appropriate multiplier for a two-sided t-test with a (0.95) confidence level.

5. Section K.1.2.6 should be consulted when data from any detector are rejected.

K.1.2.5 Examining histograms.-- The histograms will be examined by an experienced analyst. If, in the analyst's judgment, abnormalities are present, this fact will be considered further under the step described in section K.1.2.6.

K.1.2.6 Advising the Technical Advisory Team of defective data.-- The Technical Advisory Team will receive information on any data rejected by the analysis of section K.1.2.4. Any other evidence of data defects which, in the opinion of experienced analysts, might deleteriously affect subsequent processing should also be reported. The Technical Advisory Team will be requested to rule that:

1. Where the problem can be remedied, the data tapes should be regenerated.
2. Any data determined to be defective should be excluded from further processing at all three institutions.

K.1.3 Conversion and Checking of Field Coordinates

The steps to be performed after field-coordinate conversion have two functions:

1. To ascertain that all operations for reformatting the data tapes and field coordinates were performed correctly and, if not, to get the problem corrected at the ERIM and/or LARS before processing continues.

2. To provide an independent check of the accuracy of the field delineations, with the possible request for a redelineation or deletion of any fields which present problems.

The color-overprint procedure permits a rapid visual check of field delineations. Levels for the gray-tone maps will be optimized for the training areas by selecting them from histograms of data showing only the training quarter sections. The corresponding mean values in the STAT output will be used later in the preprocessing operation.

The steps for converting and checking field coordinates are set out in the following paragraphs.

K.1.3.1 Converting LARS coordinates to ERIM 'NSA' cards.- The locations of all allowable training and test fields are to be received from LARS in coordinates matching the LARSYS 3 formatted data tape. A computer program will convert these field coordinates to the ERIM 'NSA' card format. Coordinates for larger areas such as quarter sections, sections, and 3-by-3 sections will be supplied and converted similarly.

K.1.3.2 Generating histograms for the training quarter sections.- Program STAT will generate histograms and means for data only in the training quarter sections.

K.1.3.3 Mapping the designated field pixels in color.- The ADCHAN and MAPP modules under the POINT program will generate nine-level gray-tone maps of ERTS bands 5 and 7. Upon examination of the histograms generated in section K.1.3.2,

the levels will be set manually to represent equal numbers of pixels. A letter which identifies the ground cover type for each pixel in the field definitions received from LARS will be overprinted in color.

K.1.4 Definition of Major Class Signatures for Classification

The training of the processor (that is, the establishment of class signatures for use in recognition processing) is a crucial step in MSS data processing. The ERIM normally employs the interpretation and judgment of an experienced analyst as part of the training procedure. However, in keeping with the needs of the CITARS project, the ERIM has defined a procedure which minimizes this judgment factor. Although the ERIM procedures often employ more than one signature for each major class, the use of one signature per class was selected for CITARS processing because of its simplicity and processing efficiency. Furthermore, a combination of individual signatures is likely to result in a single signature encompassing more of the variability of the class than a set of individual signatures can provide.

The steps for defining major class signatures for classification are set out in the following paragraphs.

K.1.4.1 Extracting statistics for fields of major crops.— The training procedure for each major crop (corn, soybeans, or wheat) involves extracting signal statistics from each training field, analyzing these individual field statistics, and combining selected statistics to form a single class signature.

Normally, to allow adequate intrafield statistics, the ERIM would put a lower bound on the size of fields used for signature extraction. As a minimum, at least one point per channel must be present to obtain the nonsingular covariance matrix required for a usable signature, in which case the estimates of covariances would be poor. Because it is possible that a very limited amount of data will be available for fields from the ERTS data, such an arbitrary lower bound is considered inadvisable. Instead, a lesser weight will be given to small fields with fewer than (20) field-center pixels than that given to larger fields. This standard was reached after considering the following:

1. In one sense, the individual training fields are the independent samples of a given crop and should be given equal weight in the combination process.
2. On the other hand, as mentioned previously, the fewer numbers of samples from small fields indicate that their statistics are less reliable and probably should not be given the same weight as larger fields.

As a compromise, the specified weighting factors give weights to small fields that are proportional to the square root of the number of pixels in them, and all fields of 20 or more pixels are weighted equally.

It is desirable to train at least five fields for each crop, with each field having at least 20 pixels. In this manner, good statistical samples of the crop signal populations will be obtained. Program STAT will extract signal statistics from the designated field-center pixels of the ASCS ground-truthed fields of corn, soybeans, and wheat selected by NASA as training fields.

K.1.4.2 Combining, testing, rejecting, and recombining field statistics.- Signatures will be determined independently for each of the three major classes. Statistics from all designated training fields will be analyzed to determine the ones that should be combined to form the recognition signatures. The objective is to develop only signatures that are representative of healthy crops at a reasonable maturity for the time of seasons. This effort will be aided by excluding statistics from fields that are prematurely senescent, flooded, seriously stunted, or otherwise markedly deviant from the class norm and by finding and correcting any errors in the ground-truth information.

Normally, such anomalous outlier fields could be rejected by an analyst's examining the output of various programs which calculate the distances between signatures or pairwise probability of misclassification and analyzing individual field statistics such as histograms. The procedure given in this section was devised to accomplish this with an exact, reproducible algorithm to satisfy the needs of the CITARS project.

To provide a basis for comparison, the statistics from all training fields of a given class will be combined into a tentative class signature by use of the COMSCL program. A preliminary test of each individual field mean versus a χ^2 test having a rather severe threshold (PFLAG, probability of false rejection) will determine which fields might be outliers that could seriously bias the combined signature. A recombination of the remaining signatures after flagged fields are deleted will give a better estimate of the healthy crops. A final pass will test all individual field means

with this revised, combined, class signature and a more lenient threshold (PREJCT, probability of rejection) to determine which fields will actually be rejected.

This algorithm is expected to reject essentially the same outlier signatures that would be rejected by human analysts; however, it has not been tested and may need some adjustments after its performance on the first data segment is observed. The choices of probability values for PFLAG and PREJCT are expected to be somewhat data dependent; however, values established during processing of the first data set will be used throughout, unless it becomes clear (for example, a large percentage of fields are rejected) that they should be reevaluated.

The procedures of section K.1.4.2 will produce one combined signature for each of the three major classes. This signature is expected to be representative of healthy crops at a typical degree of maturity.

K.1.4.2.1 Combining field statistics: All training-field statistics for a given class will be combined by program COMSCL into one interim class signature. Equal weights will be used for large fields [$\geq (20)$ pixels], and lesser weights will be used for smaller fields. The weights for fields of fewer than (20) pixels will be $(N_i/20)^{1/2}$ times times the large-field weight, where N_i is the number of pixels in the i th small field.

K.1.4.2.2 Testing and rejecting individual field statistics: The mean vector of each individual field will be tested against the interim combined class signature derived in the previous step. The interim combined quadratic

form at the field mean of the individual field will be evaluated, and the field will be flagged as questionable if the value exceeds the χ^2 value for PFLAG.

The signatures from all nonquestioned fields will be reprogrammed using COMSCL to produce a new signature for the field elimination test that follows. The weighting for these field signatures will be the same as set out in section K.1.4.2.1.

Each individual field will be tested against this newly combined class signature by evaluating the newly combined quadratic form at the mean of the individual field; if the value exceeds the χ^2 value for PREJCT, the field will be eliminated from further consideration in training.

K.1.4.2.3 Recombining field statistics: Program COMSCL will be run a final time to combine the accepted individual field statistics into one signature for each class, using the same weights given in section K.1.4.2.1.

K.1.4.2.4 Reporting bad fields: Any rejected fields will be examined to see if a cause for anomalies can be identified. The gray maps and individual field histograms generated in previous steps will be used as ancillary information. Where appropriate, requests for ground-truth verification or redelineation will be made to the Technical Advisory Team.

K.1.4.3 Adjusting the major crop signature covariance matrices.- The signature covariance matrices will be scaled by factors derived empirically from the training data, for

the purpose of correctly classifying at least 99 percent of the points that were assigned correctly in the preliminary classification run. A single lower threshold will be used for all three classes on the final run. The empirical derivation and scaling will be used instead of the theoretical χ^2 calculation of the limit, for two reasons.

1. The Gaussian distribution assumed in calculating the theoretical χ^2 is a poor approximation of typical ERTS data with their restricted number of pixels and severe quantization problems.
2. The ERIM classification and subsequent analysis programs will use only one common exponent limit for all classes; adjustments in the signatures will have to be made, since a different optimal exponent limit could otherwise be expected for each class.

The χ^2 exponent channel of the CLASFY output contains values scaled by a multiplicative factor of 5.12. Consequently, the divisor of 94.55 given in section K.1.4.3.3 is 5.12 times the χ^2 value for the 0.001 probability of false rejection.

K.1.4.3.1 Preliminary classification run: A preliminary classification run using program CLASFY, which implements ERIM's best linear decision rule, will be made on the major crop training fields using the previously discussed corn, soybean, and wheat signatures. A χ^2 exponent limit with, in effect, no threshold (EXPLIM=99.9) will be used to generate a recognition tape containing both the classification results and the scaled likelihood function exponents.

K.1.4.3.2 Histogram exponents: The program STAT will make one histogram of the exponents generated showing correct classifications for each of the three classes. For example, the histogram for corn will be for all pixels which are from both those corn training fields used to derive the final corn signature and those recognized as corn. The scaled exponent limit necessary to accept (99 percent) of the pixels will be read off each histogram, giving a separate value for each of the three classes.

K.1.4.3.3 Scaling the covariance matrices: The COMSCL program will be used to scale separately (or normalize) the covariance matrix of each of the three signatures. The scalings will be such that, if used by CLASFY with EXPLIM set equal to 18.467 (which would give a 0.001 probability of false rejection for four channels, with Gaussian distribution), each signature would accept at least 99 percent of its training pixels that were classified correctly, as described in section K.1.4.3.2. The matrix scale factors will be computed by dividing the scaled exponent limits determined in section K.1.4.3.2 by 94.55. The means of the signatures will not be changed. These three scaled signatures will be used for the major crops in all following steps.

K.1.5 Definition of Class "Other" Signatures

Materials and ground covers other than the three major crops will be present in the segments to be analyzed. Although it is not an objective of CITARS to distinguish between them, obtaining additional signatures from some of

these ground covers will be advisable to reduce false alarms (the number of pixels from other ground covers mistakenly being called corn, soybeans, or wheat.) Since woods, lakes, and urban areas are not adequately represented in the 20 quarter sections available for training, it is expected that samples outside the 20 quarter sections will be provided as training fields for these important ground covers. Any classes "other" contributing appreciable false alarms will need a class "other" signature in the final classification run. A three-step procedure will be used, as set out in the following paragraphs.

K.1.5.1 Identifying significant other classes.- A preliminary classification run using the final corn, soybean, and wheat signatures will be made over all other identified training fields. This run will be evaluated for a classification threshold of 0.001 probability of false rejection. A likelihood map of the exponent channel, overprinted in color with the field identification from ADCHAN (see section K.1.3.3), will be generated for each major class. Exponent values greater than 0.001 will be printed as blanks.

The following will be considered as significant "other" fields:

1. Any field of 20 or fewer pixels which has (two) or more pixels classified as corn, soybeans, and/or wheat
2. Any larger field with more than (10 percent) of its pixels classified as corn, soybeans, and/or wheat

If any field (supposedly of class "other") is recognized as more than (50 percent) in one of the three major classes,

a request for verification of ground-truth identification will be made. In the meantime, processing of the segment in question will halt.

K.1.5.2 Extracting statistics for class "other" fields.- Signal statistics without editing will be extracted by program STAT for each of the significant class "other" fields determined in section K.1.5.1. Program input to omit editing will be: NOEDIT=\$ON\$.

K.1.5.3 Combining, testing, and recombining field statistics.- The statistics for all fields in each class "other" will be combined to produce one signature for each other class for the final classification run. The program COMSCL will combine the statistics into one signature, weighting the field statistics as in section K.1.4.2.1.

A check will be made to ensure that the overlap of each combined signature into any of the three major crop signatures does not exceed that of an individual field. (This could happen, for instance, if two fields, supposedly from the same class "other," lay on opposite sides of a field of corn, soybeans, or wheat.) The program LINDIST will calculate the distance (probability of miscalculation) of each combined and each uncombined class "other" signature from each of the three major crop signatures. If the combined signature for any class "other" has a greater probability of being misclassified than any of the individual signatures in its class, the ground-truth data and the distances between the pairs of individual signatures within that class will be examined. Natural groupings will then be identified for the establishment of subclass signatures.

K.1.6 Classification Without Preprocessing (ERTS-ERIM-SP1)

The signatures used throughout all classification runs will consist of:

1. The three major crop signatures (one each for corn, soybeans, and wheat) as described in section K.1.4
2. The signatures for each of the significant other classes as described in section K.1.5

In spite of the fact that the quadratic classification rule is considered theoretically to be more accurate for training data than the linear rule, the linear rule will be used because:

1. The quadratic rule is more costly in computer time.
2. Experience indicates the linear rule works satisfactorily.
3. The theoretical advantage of the quadratic rule does not necessarily carry over to test data (which might have different distributions than training data).
4. The linear rule is considered ERIM's best established technology in the sense that it will be applied to subsequent general-purpose computer work where cost is an important consideration.

The threshold for rejecting a pixel is an all-important parameter because: It controls a tradeoff between two types of error; an excess of misses or failures to classify a pixel could occur if the threshold probability of false rejection is too high; and an excess of false alarms could occur if the threshold probability of false rejection is set too low. The choice of the threshold, which will interact with the choice of class "other" signatures, will be made to help minimize

false alarm errors as discussed under section K.1.5. With suitable class "other" signatures to reduce the false alarm errors, the threshold for probability of false rejection can be set lower to reduce the number of misses. The optimum tradeoff between these two types of error will depend on how the errors will be weighted in a final analysis.

K.1.6.1 Local classification.- Local classification will be performed on the same segment from which the signatures are derived. The program CLASY will be run for each segment and its signatures with the LIN module, which applies the ERIM best linear decision rule. A threshold giving a 0.001 theoretical probability of false rejection will be applied. The class assignments and scaled exponent values will be written on a two-channel output tape.

The program TALLY will extract field-by-field statistics from the tape and punch cards of statistics for each field or other specified ground area. This output will show all pixels with exponents that are less than the theoretical χ^2 for a 0.001 probability of false rejection. The cards will give the number of pixels classified as belonging to each of the three major crop signatures, the number of pixels classified as belonging to the significant class "other" signatures (to be combined into one other class after being classified according to the individual signatures), and the number of pixels rejected by the threshold. Tallies will be produced for each of the following groups of individual areas within the local segment:

1. All ASCS ground-truthed fields used for training
2. All ASCS ground-truthed fields not used for training

3. All photointerpreted fields in the 20 sections
4. All fields in the entire 20 sections
5. The 4.8- by 4.8-kilometer, nine-section array

The tally cards will be processed and analyzed as outlined in section K.1.8.

K.1.6.2 Nonlocal classification.-- Nonlocal classification will be performed on all specified segments other than the one used for signature extraction in the same manner as the local classification described in section K.1.6.1, with the following exceptions:

1. The five groups of ground areas will be within the non-local segment.
2. To minimize the potential increases in the number of misses which might occur if and when the signatures do not completely match signals from the nonlocal area, the threshold giving the theoretical probability of false rejection will be reduced to (0.0001). Thus, the exponent limit for program TALLY will correspond to the theoretical χ^2 for (0.0001) probability of false rejection instead of the 0.001 used for local recognition processing.

K.1.7 Classification With Preprocessing (ERTS-ERIM-PSP1)

Changes in atmospheric and other local conditions can cause changes in the signal levels received at the scanner for different areas and at different times. By employing preprocessing techniques, the region of signature applicability can be extended beyond the region used for training.

Nonlocal classification will be performed twice on segments analyzed at the ERIM - once before and once after preprocessing corrections for signature extension have been applied.

K.1.7.1 Preprocessing. - A signature mean-level adjustment procedure has been selected as ERIM's best established technology for preprocessing ERTS data. Other preprocessing techniques, such as path radiance subtraction, ratios of channels, or both, are being investigated by ERIM under other contracts; and a substitution for the mean-level adjustment may be requested at a later date. Any substituted technique would be used for all data sets.

K.1.7.1.1 Preprocessing transformation: The mean-level adjustment procedure is the closest equivalent to the ACORN4 scan-angle-dependent correction function, which has been used successfully by ERIM on many different aircraft data sets. It is derived from an average over diverse ground covers within the local signature extraction segment and a comparable average within the nonlocal segment to be classified. Since averaging should be restricted to areas for which classification is of interest, only agricultural areas and vegetation will be included. The signal brightnesses of water, urban areas, clouds, and other nonvegetative features differ markedly and could seriously bias the results if included in the averages for the two segments. Segment averages will be calculated only over the areas in the 20 quarter sections, which should provide sufficient assurance of uniformity for the purposes of the CITARS project. Because the segments were preselected by NASA to include predominantly agricultural areas, large lakes, urban areas, and cloudy data will be excluded from this study.

The preprocessing transformation will be based on the averages of signals over the 20 quarter sections selected by NASA for ASCS ground-truth data acquisition and classification training. The means computed in section K.1.3.2 for the training segment and for the segment to which the signatures are to be extended will be used.

K.1.7.1.2 Adjustment of signatures: Because the ERTS sensor views the Earth through the entire atmosphere and a substantial part of the received signal is from additive path radiance, an additive correction was selected in preference to the multiplicative adjustment of signatures. Also variations in atmospheric conditions, which are expected to be the major source of intersegment variations in recorded signals, can be adjusted most appropriately by an additive correction.

The means of each of the signatures will be adjusted separately for each channel by adding the difference in signal means from the previous step.

$$\mu_{nl,k} = \mu_{l,k} + (m_{nl,k} - m_{l,k}) \quad (K-2)$$

where k denotes one of the four ERTS channels, l denotes the local segment used for signature extraction, nl denotes the nonlocal segment to be used for classification, μ is a signature mean for one of the classes, and m is a data mean over the 20 quarter sections calculated as described in section K.1.2.3.

Although it may be considered as the logically equivalent opposite adjustment to the data values, the additive correction

will be applied to the signature means as a matter of convenience. It will not alter the signature covariance matrices; whereas, if a multiplicative effect were the predominant source of variations, scaling the covariance matrices would be advisable.

K.1.7.2 Classification.- Preprocessed classification will be performed on the nonlocal segments as described in section K.1.6 except:

1. All the signatures will have the adjusted means $\mu_{nl,k}$ calculated as described in section K.1.7.1.2.
2. An exponent threshold corresponding to the theoretical χ^2 for (0.0001) probability of false rejection will be used with TALLY instead of the χ^2 for 0.001 probability used for local classification.

K.1.8 Postrecognition Analysis

K.1.8.1 Modification of program TOTAL.- The existing TOTAL program, which calculates average classification accuracies, will be modified to produce outputs in the form required for analyses by the EOD.

K.1.8.2 Execution of program TOTAL.- The TOTAL program will be run using the individual field statistics cards punched by the TALLY program as data (see sections K.1.6.1, K.1.6.2, and K.1.7.2). The data for each of the five groups of areas listed in section K.1.6.1 will be processed separately. TOTAL will print tables of average classification results over all fields within the group for each signature class for corn, soybeans, wheat, all other, and

rejected (not recognized within the threshold) classes versus each corresponding ground-cover class. At the same time, it will generate data for the EOD analysis in a format to be specified.

K.1.9 Classification With the Quadratic Decision Rule

One of the CITARS task goals is to compare and evaluate various types of MSS data processing and analysis procedures. The preferred ERIM classification procedure uses the linear decision rule, as set out in section K.1.6. In order to establish a valid comparison between results obtained by processing with the linear and quadratic decision rules in the CITARS context, selected data sets will be processed with a quadratic maximum likelihood decision rule. The use of both decision rules by one organization will eliminate any confusion that may be caused by differences in the training procedures used at the LARS, EOD, and ERIM.

K.1.9.1 Classification without preprocessing (ERTS-ERIM-SP2)..- This procedure will be exactly as described for the linear decision rule in sections K.1.4 through K.1.6 and K.1.8, except that the QRULE module under the POINT processing system will be employed for classification.

K.1.9.2 Classification with preprocessing (ERTS-ERIM-PSP4)..- This procedure will be as described previously for the linear decision rule with signature extension preprocessing (sections K.1.4 and K.1.5, K.1.7 and K.1.8), except that the QRULE module under the POINT processing system will be employed for classification.

K.1.10 Procedures for Estimating Proportions With a Mixtures Algorithm (ERTS-ERIM-SP3/SP4)

It is recognized that the spatial resolution of scanner data obtained from space altitudes may be too poor to estimate crop acreages adequately by conventional recognition techniques. For example, the instantaneous field of view of ERTS-1 may include portions of several agricultural fields containing distinct crops. In general, the radiation from such an instantaneous field of view will not be characteristic of any one of the materials in it. In addition, the ground area associated with one pixel (approximately 57 by 79 meters) is not exactly equal to the ground area of an ERTS-1 instantaneous field of view (79 by 79 meters). Thus, a pixel associated with that instantaneous field of view may be misclassified or rejected by conventional classification algorithms. Frequent recurrences could cause the overall estimates of crop acreages to be inaccurate. Therefore, ERIM has developed a mixtures algorithm to estimate proportions of materials for single pixels or groups of pixels. Experience has shown that this algorithm can be more effective than conventional algorithms in estimating proportions over areas with a number of large pixels. This algorithm will be used to estimate major crop acreage in the CITARS areas of interest.

Given a signal vector y , the mixtures algorithm will either estimate a vector λ of proportions or decide that y does not represent a mixture of the materials for which signatures are given. It should not estimate λ if the pixel contains a large amount of alien or unknown material. The alien object test is a special type of χ^2 test for

detecting this situation. It is analogous to the χ^2 test used in conventional recognition processing. Any pixel rejected as not classified in conventional processing will either be a mixture of the specified materials or an alien object in mixtures processing.

The mixtures algorithm estimates a proportion vector λ from a data vector y by maximum likelihood. If A_λ is the mixtures mean vector given by the ERIM model for mixtures statistics (see section 2 of *Estimating Proportions of Objects from Multispectral Data* by R. F. Nalepka, H. M. Horwitz, and P. D. Hyde, Report 31650-73-T, Willow Run Laboratories, University of Michigan, March 1972), and M is the average of the covariance matrices of the signatures of the constituent materials in the mixture, then the desired λ is found by minimizing

$$G(\lambda) = \left\| (y - A_\lambda) P^T \right\|^2$$

$$P^T P = M^{-1} \quad (K-3)$$

subject to the constraints

$$\lambda^i \geq 0 \quad \text{for } i = 1, \dots, m$$

$$\sum \lambda^i = 1 \quad (K-4)$$

This is a quadratic programming problem, and the optimum λ is found by the method of Theil and Van de Panne, as set out in *Nonlinear Programming* by H. P. Kunen, et al., Blaisdell, 1966.

Proportions over an area consisting of several pixels can be estimated in one of two ways.

1. Point-by-point estimation: Proportion vectors are estimated separately for each nonalien pixel in the area and then averaged over the area of interest.
2. Estimation with averaging: Alternatively, the nonalien data vectors for the pixels are averaged, and the estimated averaged proportions are computed directly from the averaged data vector.

Estimation with averaging is faster because it requires fewer estimations. Program MIXMAP has been written to implement estimation of proportions by maximum likelihood and Theil and Van de Panne. Average proportions over an area will be computed, and the user may specify whether they are to be computed point-by-point or with averaging, or both. Both will be used for CITARS processing. The user may also specify whether to use an alien object test, as will be done for CITARS, and input a value for the χ^2 threshold. The MIXMAP output for point-by-point estimation can be mapped to show the pixel-by-pixel content of each material on a separate output.

K.1.10.1 Locating training areas.- The quality of data to be used for both training and testing will have been checked as described in section K.1.2, and digital gray maps

will be produced for all training areas. The data analyst will use these maps and the corresponding ground-truth information to

1. Locate fields which might be used for training
2. Determine the location and number of field-center pixels for each material known to be in the area
3. List the materials and corresponding training sets for those materials having (50) or more field-center pixels
4. Compute the approximate proportion of the material over these training data

K.1.10.2 Defining signatures. - The main purpose of the mixtures processing for CITARS is to obtain good estimates of corn, soybean, and wheat proportions in the areas of interest. Other substances in the region, as long as they differ from the three major crops, do not need to be distinguished. However, to assure the best possible quality of estimates for proportions of the major crops, it is desirable to add signatures for other vegetation in the scene. Conflicting criteria exist for choosing other signatures:

1. These signatures should represent crops or vegetation in substantial amounts.
2. In order that proportion estimates of the major crops will not be decreased, the other substances should be the signatures spectrally closest to combinations of corn, soybeans, and wheat.

Because ERTS provides only four channels, the proportions of only five materials can be estimated. These must,

of course, include corn, soybeans, and wheat (wheat may be omitted if not present in sufficient amounts).

K.1.10.2.1 Major crop signatures: The signatures generated for corn, soybeans, and wheat using conventional recognition processing (section K.1.7) will be used for these crops, if they are present in sufficient amounts.

K.1.10.2.2 Other signatures: The other signatures will be obtained in the manner described in section K.1.4; however, the choice of other vegetation will be made differently, and the covariance matrices will not be adjusted. Initially the analyst will generate a signature S_i for each other substance for which (50) or more field-center pixels are present in the training data identified by the LARS. The value a_i will be the approximate proportion of material i in the training data obtained according to section K.1.10.1.

Before the signature materials can be chosen, it must be determined that a signature is spectrally close to a combination of certain others. Program GEOM, which is actually part of the MIXMAP program, will perform this task by

1. Computing the shortest distance from a vertex A_i of a signature simplex to the subsimplex (opposite face) formed by the remaining vertices (a distance in probability from the i th material to the set of mixtures of the others)
2. Computing a distance r_i from a proposed crop signature S_i to the simplex formed by the major crop signatures (The numbers r_i , in turn, will be used to determine the other signature substances to be used.)

Depending on whether a wheat signature will be included, either two or three signatures may be added to the signature set to make a total of five signatures. If $\Phi(x)$ is the normal probability integral, then the probability of misclassifying material i with a mixture of the others is approximately $\Phi(-r_i/2)$, where r_i is obtained from GEOM. If a_i is the proportion of material i in a typical scene, in order to choose the two or three additional signature materials, it is desirable to maximize both a_i and $\Phi(-r_i/2)$. Since this may not be possible, the materials which give the two or three largest values of $a_i \Phi(-r_i/2)$ will be added to the signature set.

$$t_i = a_i \Phi(-r_i/2) \quad (K-5)$$

where Φ is the normal probability integral. To complete the signature set, all S_i which correspond to the two or three largest t_i will be added.

K.1.10.3 Alien object threshold.— If a data vector y from a given pixel does not represent a mixture of the materials represented by the signature set and proportions are estimated from such a pixel, the estimated proportions of these materials may be distorted. A simple statistical test may be employed to determine whether a pixel contains alien items rather than a mixture of the prescribed materials. This special χ^2 test will be based on the distance from y to the signature simplex. If the distance is greater than a certain threshold value, the pixel corresponding to y will be rejected as alien and no proportions will be estimated. For a given χ^2 value, all points rejected by

this test will also be rejected by the χ^2 test for the recognition processing, but not conversely. A threshold value for χ^2 which is somewhat dependent on the data should be chosen.

In order to choose a desirable χ^2 value for the alien object threshold, one should use as much information inherent in the training data as possible. The signature covariance matrices and the adjustments made in the major crop-signatures account for some, but not all, of the variations in the data. The effect of other materials, especially those not included in the final signature set, should be considered. The method for choosing the most accurate χ^2 is strictly empirical. The mean square error in the average point-by-point estimated proportions over the training area as a function of χ^2 will be computed for each of (nine) selected χ^2 values. The (nine) selected values will be centered around the 0.001 rejection probability value used in local recognition processing. The corresponding rejection probabilities will be (0.01, 0.0056, 0.0032, 0.0018, 0.001, 0.00056, 0.00032, 0.00018, and 0.0001). The χ^2 value to be used as the alien object threshold will be that selected value which minimizes the error for the training data.

K.1.10.3.1 Processing training data: In practice, there are two related but slightly different alien object tests. One is the screening test and the other is the true distance test. The true distance test is the alien object test performed after estimating the proportions which are required to compute the actual distance. The screening test very quickly computes a lower bound for the distance from the data vector y to the simplex. If the lower bound is

greater than χ^2 , y will be rejected as alien. Clearly, use of the screening test will provide considerable savings in computer time.

The screening test will be performed for each of the nine selected χ^2 values used as alien object thresholds by:

1. Obtaining via MIXMAP point-by-point estimation the estimated proportions over each of the 10 training quarter sections
2. Computing the norm square of the difference between true and estimated proportion vectors for each training quarter section
3. Averaging the errors resulting from step 2 over the 10 quarter sections to obtain error corresponding to χ^2

K.1.10.3.2 Determining the χ^2 threshold: The alien object χ^2 threshold will be a selected value which minimizes the error obtained in step 3 above.

K.1.10.4 Processing test data.- When the signature set has been determined and the data are prepared (as in conventional processing), the data will be processed through the mixtures algorithm. For each test area of data, the estimation will be done both point-by-point and with averaging. The average estimated proportions from both methods will be printed out for each section. The results for each section will indicate how many pixels were used for estimation and how many were rejected as alien.

From this information the proportions of corn, soybeans, wheat, and other substances can be easily computed.

Test data will be read in from sections and any larger areas in each segment and processed using program MIXMAP. Input will include

1. A deck containing the final signature set
2. Control cards specifying the key parameters, including the number of signatures and channels, the appropriate threshold value for the alien object tests, and flags to denote that
 - a. The alien object tests are to be implemented
 - b. Both point-by-point estimation (ERTS-ERIM-SP3) and estimation with averaging (ERTS-ERIM-SP4) are to be performed.

The program MIXMAP is a module of the POINT processing system, and the input control cards will be set up accordingly. The standard output for each test section will include

1. N_1 = the number of pixels used to estimate proportions
2. N_2 = the number of pixels rejected as alien
3. Proportions of materials estimated point-by-point (over all nonalien pixels in the section)
4. Proportions of the materials estimated with averaging (over all nonalien pixels)

K.1.10.5 Preparing final output.- The desired results of this processing are the estimated proportions of corn,

soybeans, wheat, and other substances over each entire section of data, including both the pixels used for estimation and those rejected as alien. Because MIXMAP will estimate proportions only over the set of pixels not rejected as alien, to obtain data over an entire section, each proportion must be multiplied by that fraction of pixels representing nonalien material. The estimated proportions of corn, soybeans, and wheat will be modified accordingly. In the final result, the total proportion of class "other" will be the sum of the modified other proportions (represented by signatures) and the fraction of pixels rejected as alien.

If λ_1 , λ_2 , and λ_3 are the estimated proportions of corn, soybeans, and wheat and λ_4 and λ_5 correspond to the two other signatures, the total proportions over the entire section will be:

$$\lambda'_1 = \frac{N_1}{N_1 + N_2} \lambda_1$$

$$\lambda'_2 = \frac{N_1}{N_1 + N_2} \lambda_2$$

$$\lambda'_3 = \frac{N_1}{N_1 + N_2} \lambda_3$$

$$\lambda(\text{other}) = \frac{N_1}{N_1 + N_2} (\lambda_4 + \lambda_5) + \frac{N_2}{N_1 + N_2} \quad (\text{K-6})$$

The final results will be recorded on cards or on tape according to the EOD specified format. Thus, each proportion estimate will be represented by the equivalent number of pure pixels over the entire area.

K.2 AIRCRAFT MSS DATA

K.2.1 Reformatting of the Data

Aircraft data will be received in LARSYS 3 format and converted to the ERIM format as described in section K.1.1.

K.2.2 Conversion of Field Coordinates

The locations of all training and test fields, quarter sections, sections, and other larger areas such as 3-by-3 sections will be received from LARS in coordinates that match the LARSYS 3 formatted data tapes. These coordinates will be converted to the ERIM 'NSA' card format as specified in section K.1.3.1.

K.2.3 Verification of Data Quality

Some standard data quality checks will be made by the EOD during tape conversion. The ERIM will also apply some of its standard methods of monitoring data quality in order that any discrepancies can be brought to the attention of the Technical Advisory Team before further processing.

K.2.3.1 Generating gray maps.- Digital gray maps will be generated for the 20 test sections for two channels in the red and infrared portions of the spectrum. The exact

wave bands will depend on the scanner used. Standard darkness symbols will be applied to nine spectral levels, each of which will be determined separately for each channel by the automatic level-set feature. In addition, gray maps of smaller selected test areas will be generated for all channels for use in the skew check described in section K.2.3.3. These areas will show roads or other sharp boundaries between contrasting features.

K.2.3.2 Generating histograms, means, and standard deviations.- The STAT program will be run without editing (NOEDIT=\$ON\$) over a selected test area to generate one histogram per channel, signal means, and standard deviations.

K.2.3.3 Checking for skew.- The gray maps from section K.2.3.1 will be examined to ascertain that the boundaries fall on the same pixels in all channels; if they fail to do so in any channel, the amount of deviation will determine the skew of that channel in relation to the others.

K.2.3.4 Examining data for defects.- An experienced analyst will examine the histograms and gray maps generated above for signs of defective data, as described in section K.1.2. If the analyst finds evidence of data defects or skew which might have a deleterious effect on subsequent processing, this will be reported to the Technical Advisory Team, as set out in section K.1.2.6.

K.2.4 Verification of Field Delineations

The procedures for verifying field delineations will follow those set out in section K.1.3.

K.2.4.1 Mapping designated field pixels in color.- An ADCHAN color map of letters that identify the field types will be printed over gray maps for the two channels generated as outlined in section K.2.3.1.

K.2.4.2 Examining the field delineations.- The field delineations will be examined on the color maps described in section K.2.4.1, and any problems will be reported to the Technical Advisory Team, as discussed in section K.1.3.3.

K.2.5 Preprocessing Data for Scan-Angle Variations

(Aircraft-ERIM-PSP2)

Signal variations with scan angles up to $\pm 6^\circ$ over one ERTS frame are minor when compared with local atmospheric variations; however, in aircraft data having scan angles up to about 45° , the variation in the recorded signal is predominant. As a standard operating procedure, ERIM will apply a scan-angle correction to aircraft data before other processing is undertaken.

K.2.5.1 Deriving scan-angle corrections.- The ERIM ACORN4 program has been selected for the average signal-versus-angle data transformation. This technique calculates an average correction for each scan angle. The correction function is derived by computing an average signal at each scan angle for each channel. The ACORN4 program will produce quadratic, multiplicative, scan-angle corrections for each of the passes over a given segment. As explained in section K.1.7.1, sizable water, urban, and cloud areas will in effect be excluded by limiting the averaging to the quarter sections preselected by NASA. To arrive at a

smooth correction function, a second order polynomial will be fit to these average signals. This function is indicative of the average angular variation in the corresponding channel of data. Correction will then be made by dividing the data by the correction functions. All subsequent processing will be done on the corrected tapes.

The application of ACORN4-type corrections has been the most uniformly successful and reliable technique used by ERIM on many different aircraft data sets. Its selection is appropriate for the CITARS project where it is desirable to use the most reliable established technology.

K.2.5.2 Adjusting corrections.- In most instances, each segment will be covered by two adjacent passes of the aircraft scanner. Because of time delays or other variables, the average signal level from the second pass might be different from what it would have been if data had been collected simultaneously with those of the first pass. Where more than one pass is made over a segment, a multiplicative factor will be computed to adjust the scan-angle corrections from one pass so that its mean value after correction matches that of the first pass after correction.

K.2.5.3 Applying the corrections.- The program APPLY will apply the ACORN4 corrections to data for each test section and 3-by-3 section area. This scan-angle-corrected data will be used in all subsequent processing.

K.2.5.4 Generating abridged data tape.- When the scan-angle corrections are applied, a shortened data tape will be

generated to hold 21 files, one for each test section and one for the 3-by-3 section area. The original scan line and point numbers will be preserved. This procedure will reduce the tape movement time on subsequent processing.

K.2.6 Definition of Signatures for Classification

This training on aircraft data follows essentially the same procedure explained in sections K.1.4 and K.1.5, with one difference. Because of the small fields available on ERTS data, a lower bound of 20 pixels on an individual field was established. This was a compromise between the poor statistics in a signature covariance matrix from fewer pixels on the one hand and the anticipated dearth of larger fields on the other. A lower bound for aircraft data is also advisable; and, with the improved covariance matrices, a considerably larger limit will be set. The exact limit chosen will depend on the scanner used and the altitude of the aircraft. At the present time, the estimate of 100 pixels is practical for the minimum field size needed for the MSS aircraft flights on the CITARS project.

Therefore, one signature will be derived for each of the three major crops of corn, soybeans, and wheat. The method described in section K.1.4 will be used, except the lower bound of 20 pixels for an individual large field will be replaced by (100) pixels. Similarly, the signatures for significant classes "other" will be derived as set out in section K.1.5, except the 20-pixel lower bound will be replaced by (100).

K.2.7 Selection of Subsets of Channels

K.2.7.1 Selecting channels for local classification.-

When a final set of combined signatures has been defined, the program STEPLIN will select a subset of channels for local classification for each training segment. The STEPLIN program will employ a linear approximation to calculate the probability of misclassification. It will process the set of signatures from section K.2.6, considering the pairwise probability of misclassification among the three major class signatures and between each of these three and each class "other" signature. When STEPLIN has made its selection, the number of best channels will be such that the estimated average pairwise probability of misclassification will not exceed (1.05) times the average misclassification using all channels. This number of selected best channels will be used for all subsequent local classification processing with this signature set.

K.2.7.2 Selecting channels for nonlocal classification.-

The procedures described in section K.2.7.1 will be followed in selecting a subset of channels for nonlocal classification.

K.2.7.3 Selecting channels for signature extension.-

During the selection of channels for nonlocal classification with signature extension (mean-level adjustment), the thermal channel will be excluded. The criterion for this exclusion is the belief that the relative signal levels between the major classes will vary more in the thermal than in the reflective bands. Thus, for nonlocal classification with

preprocessing for signature extension, the procedures set out in section K.2.7.1 will be repeated, omitting the thermal channel or channels.

K.2.8 Classification Without Signature Extension (Aircraft-ERIM-PSP2)

Processing will be the same as described in section K.1.6, except that

1. The ERTS data in section K.1.6 is completely unprocessed.
2. The aircraft data and signatures used in this section are preprocessed within a segment by the ACORN4 scan-angle-correction method.
3. The aircraft data and signatures in this section are not preprocessed by the signature extension (mean-level) adjustment to a different segment, the description of which will be set out in section K.2.9.

K.2.8.1 Local classification.-- The ERIM best linear decision rule, with the LIN module under the CLASFY program (section K.1.6.1), will be used with the signatures and selected channels described in sections K.2.6 and K.2.7, respectively, to classify the scan-angle-corrected data generated according to section K.2.5.

K.2.8.2 Nonlocal classification.-- The procedures set out in section K.1.6.2 will be followed for nonlocal classification of the scan-angle-corrected data from section K.2.5 for segments other than the one used for signature extraction.

This processing will incorporate the signatures of section K.2.6 and the selected channels of section K.2.7.

K.2.9 Classification With Signature Extension (Aircraft-ERIM-PSP3)

The procedures set out in section K.1.7 will be followed in preprocessing aircraft data. An additive signature mean-level adjustment was considered best to correct ERTS data for the path radiance. However, at aircraft altitudes, path radiance effects are generally less important than irradiance, transmittance, and directional reflectance effects (especially in the longer wavelength bands frequently selected for crop discrimination). Therefore, a multiplicative adjustment is considered more appropriate for aircraft data.

K.2.9.1 Preprocessing.— A signature mean-level adjustment technique similar to that used in section K.1.7 has been selected for the aircraft data. The data means will be extracted from the scan-angle-corrected data of section K.2.5. As in section K.1.7, this will be done from the 20 quarter sections in each of the two segments involved. The multiplicative adjustment to the signature means will be made as follows:

$$\mu_{nl,k} = \mu_{nl,k} \cdot (m_{nl,k}/m_{l,k}) \quad (K-7)$$

with the corresponding scaling of the covariance matrices:

$$C_{k,k'}^{nl} = C_{k,k'}^l \cdot \sqrt{\frac{m_{nl,k} \cdot m_{nl,k'}}{m_{l,k} \cdot m_{l,k'}}} \quad (K-8)$$

where k and k' are the two channels indexing a given row and column of the signature covariance matrix; $C_{k,k'}^{\ell}$ and $C_{k,k'}^{nl}$ are the (k,k') elements of the covariance matrices for a signature from the local (signature extraction) and the nonlocal segment, respectively. The other notation is as given in section K.1.7.1.

K.2.9.2 Classification.- The procedures set out in section K.1.7.2 will be followed when classifying for signature extension of the scan-angle-corrected data from section K.2.5. This processing will incorporate the subset of channels selected in section K.2.7.2 and the signatures as modified in section K.2.9.1.

K.2.10 Postrecognition Analysis

The procedures for postrecognition analysis will follow those set out in section K.1.8. The TOTAL program will generate data for EOD analysis exactly as set out in section K.1.8.2.

K.3 IDENTIFICATION OF ERIM MSS PROCESSING PROCEDURES

Table K-I is a summary of the data-gathering sources, ADP techniques, and methods used by ERIM for MSS processing. Table K-II is a summary and description of the computer programs used for the various phases of ERIM MSS processing.

TABLE K-I.— SUMMARY OF ERIM MSS PROCESSING PROCEDURES

| <u>Data source/ ADP technique</u> | <u>Method used</u> |
|---------------------------------------|--|
| ERTS-ERIM-SP1 | Linear decision rule |
| ERTS-ERIM-SP2 | Quadratic decision rule |
| ERTS-ERIM-SP3 | Mixtures point-by-point processing |
| ERTS-ERIM-SP4 | Mixtures processing with averaging |
| ERTS-ERIM-PSP1 | Quadratic decision rule with signature extension preprocessing |
| ERTS-ERIM-PSP4 | Linear decision rule with scan-angle-correction preprocessing |
| Aircraft-ERIM-PSP2 | Linear decision rule with scan-angle-correction preprocessing |
| Aircraft-ERIM-PSP3 | Linear decision rule with both scan-angle-correction and signature extension preprocessing |

TABLE K-II.- SUMMARY OF ERIM MSS PROCESSING PROGRAMS

| <u>Program</u> | <u>Description</u> |
|----------------|--|
| ACORN4 | Derives a correction for scan-angle-dependent variations in the data. The correction function can be either multiplicative or additive; and a separate function, which is a quadratic function of the scan angle, is used for each channel. The function is determined from a quadratic least squares fit to the average scan line. The average is over many scan lines along the flight-path and includes random samples of ground covers at each scan angle. |
| ADCHAN | Identifies ground-truth fields or other areas by encoding information such as the crop type in extra channels added to the data. The MAP program can use this information to automatically display the selected fields. |
| APPLY | Applies corrections to the data derived by ACORN4 or other programs. Any additive and/or multiplicative corrections which are functions of the scan angles and channels can be applied. |
| CLASFY | Uses either the best linear or the quadratic recognition rule to classify the data point by point into ground-cover types according to signatures from STAT. CLASFY may be used in one of two ways: <ol style="list-style-type: none">1. It can be run over an entire set, in which case the normal output will be a recognition tape containing the class and scaled likelihood function exponent for each point; the MAP program can then map the tape to show how each data point was classified, rejecting points with less than a specified probability of being from the assigned class. |

TABLE K-II.— SUMMARY OF ERIM MSS PROCESSING

PROGRAMS - Continued

| <u>Program</u> | <u>Description</u> |
|----------------|--|
| | 2. It can be run over individual ground-truthed fields to print information on how many points in each field were classified according to each signature class; this information can then be punched on cards for subsequent analysis by the TOTAL program. |
| COMSCL | Combines the distributions of a set of signatures, presumably all for the same ground cover, with optional weighting of the individual signatures or scaling of the signatures; it can also calculate the distance of individual signature means from a combined signature. |
| LINDIST,DIST | Determines how well separated a set of signatures is by calculating a pairwise probability of misclassification between each possible pair of signatures; a linear (LINDIST) or quadratic (DIST) recognition rule is used. |
| MAP,MAPP | Produces a digital map on a line printer by overprinting two characters to generate various darknesses for gray tones. The same program produces color maps using black, red, blue, and green ribbons for successive passes through the line printer. The gray tones can represent the signal level in a specified channel, or the CLASFY routine output can be mapped to show how each data point was classified. |

TABLE K-II.- SUMMARY OF ERIM MSS PROCESSING
PROGRAMS - Continued

| <u>Program</u> | <u>Description</u> |
|----------------|---|
| POINT | A master program to run many routines in a series; many of the aforementioned routines are written to be called by POINT; it takes care of most of the bookkeeping details of calling PROCESS to read and handle the data and of passing the data to any specified set of routines, one data point at a time. |
| STAT | With its subroutines immediately below, extracts signatures and related statistics from specified data fields. An editing algorithm optionally rejects atypical data points such as noise spikes. |
| SIG | A subroutine of STAT, generates the signatures (the data mean in each channel over the specified field, minus edited points, plus the covariance matrix). |
| HIST | A subroutine of STAT, prints two histograms of the number of points having each data value in each channel, one for the points accepted and one for the points edited out. |
| POSDEF | A subroutine of STAT, prints the eigenvalues and eigenvectors of the covariance matrix. |

TABLE K-II.- SUMMARY OF ERIM MSS PROCESSING

PROGRAMS - Concluded

| <u>Program</u> | <u>Description</u> |
|-----------------|---|
| STEPLIN,STEPERR | Examines a set of signatures to rate the channels to be used for classification as best, second best, and so forth. The pairwise probability of misclassification is calculated according to a linear (STEPLIN) or quadratic (STEPERR) rule, between all pairs of signatures, using the channels selected at that point and each of the remaining channels in turn. The next-selected channel will be the one that gives the lowest average probability of misclassification between signature pairs. |
| TALLY | Reads individual fields on the recognition tape written by CLASFY to generate information on recognitions performed in known areas; it is equivalent to running CLASFY on each individual area. |
| TOTAL | Receives the field-by-field punched cards of CLASFY or TALLY as input and, according to several formulas, calculates the average correct recognition and various kinds of errors. |

APPENDIX L

DESCRIPTIONS OF FACTORIAL ANALYSES

APPENDIX LDESCRIPTIONS OF FACTORIAL ANALYSES

The following report samples give greater detail to the factorial analysis descriptions. The question numbers, which are given in order of priority, refer to the questions set out in section 5.4 of the Task Design Plan. The presence of number 11 on each analysis means that analyses will be performed on combinations of the factors associated with the relevant question numbers.

L.1 ANALYSIS I

Organization: ERIM, LARS, EOD

Type of Data: ERTS

Factors:

- Segments - six
- Times - two
- ADP techniques - ERTS-ERIM-SP1,
ERTS-LARS-SP1 or -SP2, ERTS-EOD-SP1

Question Answered: 1, 2, 3, 11

Comments: This analysis will provide a crop classification performance (CCP) comparison on a common data set for two data acquisition periods for local training/local recognition. Subsequent analyses will determine the CCP of these techniques for local training/nonlocal recognition.

L.2 ANALYSIS II

Organization: LARS, EOD

Type of Data: ERTS

Factors:

- Segments - six
- Times - five
- ADP techniques - ERTS-LARS-SP1,
ERTS-EOD-SP1

Question Answered: 3, 2, 1, 11

Comments: This analysis, which supplements analysis I, will provide information about all of the time periods. Differences established between ERIM and other standard ADP techniques in analysis I will be assumed to hold for the remainder of the data acquisition periods. Thus, provided the above assumption is valid, this analysis can provide CCP information about ERTS-ERIM-SP1 at other time periods.

L.3 ANALYSIS III-A

Organization:

ERIM

Type of Data:

ERTS

Factors:

- Local training/local recognition and local training/nonlocal recognition - four local and ten nonlocal combinations
- Times - two
- ADP techniques - ERTS-ERIM-SP1, ERTS-ERIM-PSP1

Question Answered: 6, 5, 2, 11

Comments:

Primarily this analysis will examine the effect of preprocessing ERTS data. Only ERIM procedures will be used here so the preprocessing will not be confounded with other factors.

L.4 ANALYSIS III-B

Organization: ERIM, LARS, EOD

Type of Data: Aircraft (unrestricted)

Factors:

- Local training/nonlocal recognition, local training/local recognition - four local and six nonlocal combinations
- ADP techniques - Aircraft-ERIM-PSP2, Aircraft-ERIM-PSP3, Aircraft-LARS-SP1, Aircraft-EOD-PSP1

Question Answered: 6, 5, 11

Comments:

This analysis will provide a cross-comparison between EOD and ERIM preprocessing techniques for aircraft data. Also, the LARS unprocessed technique will be compared with the EOD and ERIM methods. It is assumed that the same preprocessing technique applied to the LARS or EOD basic ADP procedure would have a similar effect.

L.5 ANALYSIS IV-A

Organization: LARS, EOD, ERIM

Type of Data: ERTS

Factors: ● Local training/nonlocal recognition -
 10 combinations
 ● ADP techniques - ERTS-LARS-SP1,
 ERTS-EOD-SP1, ERTS-ERIM-SP1

Question Answered: 5, 1, 11

Comments: This analysis is designed to evaluate
 and compare the three standard tech-
 niques for various local training/
 nonlocal recognition conditions.
 Analysis IV-B (LARS only) covers more
 extensive local training/nonlocal
 recognition combinations. It will be
 assumed that differences between LARS
 and EOD/ERIM would carry over to the
 combinations of local training/nonlocal
 recognition used in analysis IV-B.

L.6 ANALYSIS IV-B

Organization: LARS

Type of Data: ERTS

Factors:

- ERTS passes - same and different, with various factors (40 combinations)
- Segments - same and different, with various factors
- Times - three
- ADP technique - ERTS-LARS-SPl

Question Answered: 5, 3, 2, 11

Comments:

This analysis will examine different aspects of local training/nonlocal recognition than those examined in analysis III. Analysis III will determine the effect of preprocessing on local training/nonlocal recognition for both aircraft and satellite data, whereas analysis IV-B will evaluate discrepancies in CCP as a function of

1. Training on one ERTS orbit and classifying on another, with the same location
2. Training on the same ERTS orbit with adjacent locations

3. Training on one ERTS orbit and classifying during the succeeding data acquisition period, with the same location
4. Pooling statistics from several segments to classify same
5. Determining the effect of east-west versus north-south orbit on local training/nonlocal recognition

Some of the 40 combinations of local training/nonlocal recognition will have been processed in analyses III-A and IV-A.

L.7 ANALYSIS IV-C

Organization: LARS, EOD

Type of Data: ERTS

Factors:

- ERTS pass - same and different, with various factors (10 combinations)
- Segments - same and different, with various factors
- Times - one
- ADP techniques - ERTS-LARS-SP1, ERTS-EOD-SP1

Question Answered: 5, 3, 2, 11

Comments: This analysis is a subset of analysis IV-B. It compares the signature extension performances of standard ADP techniques at LARS and EOD. The differences detected here will be assumed valid for the results of analysis IV-B so that additional information may be gained with regard to the EOD technique for different times.

L.8 ANALYSIS V-A

Organization: LARS, EOD, ERIM

Type of Data: ERTS and aircraft (unrestricted)

Factors:

- Segments - two
- Times - two
- ADP techniques - ERTS-LARS-SP1, M²S-LARS-SP1, ERTS-EOD-SP1, M²S-EOD-SP1, ERTS-ERIM-SP1, M²S-ERIM-SP2

Question Answered: 4a, 2, 3, 1, 11

Comments: This analysis will provide information about differences between satellite and unrestricted aircraft M²S data. Each organization will analyze ERTS and M²S data for two times and two segments.

L.9 ANALYSIS V-B

Organization: LARS

Type of Data: ERTS and aircraft (unrestricted)

Factors:

- Segments - six
- Times - five
- ADP techniques - ERTS-LARS-SP1,
M²S-LARS-SP1

Question Answered: 4a, 2, 3, 1, 11

Comments: This will be an extension of analysis V-A, covering all times and segments for LARS only. It is assumed that differences between ERIM, EOD, and LARS will carry over to the segments and times not analyzed by ERIM and EOD.

L.10 ANALYSIS VI

Organization: EOD

Type of Data: ERTS and aircraft

Factors:

- ERTS and aircraft passes - four ERTS channels, feature extraction, and ERTS-B channels
- Segments - two
- Times - two

Question Answered: 4b, 4c, 2, 3, 11

Comments:

Significant differences in CCP will be established among the three types of aircraft scanner bands and ERTS-1 for local training/local recognition using the EOD procedure SP1 with feature selection, bands similar to ERTS-1, and bands similar to ERTS-1 with thermal channels.

L.11 ANALYSIS VII

Organization: EOD

Type of Data: ERTS

Factors:

- Local training/local recognition and local training/nonlocal recognition - eight selected combinations
- Times - unitemporal and multitemporal combinations
- ADP technique - ERTS-EOD-SP1

Question Answered: 7, 5, 11

Comments: This analysis will determine the effectiveness of multitemporal processing on both local training/local recognition and local training/nonlocal recognition. The local training/local recognition data set will consist of

1. Two passes, one before wheat harvest and corn tassel and one after tasseling (three segments)
2. Five registered passes (two segments)

The local training/nonlocal recognition will consist of data sets 1 and 2 described above, using different segments/same orbit and different segments/

different orbit to examine the east-west versus north-south signature extension problem.

These performance numbers will be compared to unitemporal recognition.

L.12 ANALYSIS VIII

Organization: LARS, ERIM, EOD

Type of Data: ERTS

Factors:

- Segments — six, field centers only, whole fields
- Times — two
- ADP techniques — ERTS-LARS-SP1 or -SP2, ERTS-EOD-SP1, ERTS-ERIM-SP1

Question Answered: 8, 1, 2, 3, 11

Comments: This is the same as analysis I with an added factor: field centers versus boundaries. No extra classifications will be involved, and classification results will be tabulated for centers only.

L.13 ANALYSIS IX

Organization: LARS, ERIM

Type of Data: ERTS

Factors:

- Training sets - two sets of training fields per segment
- Segments - six
- Times - two
- ADP techniques - ERTS-LARS-SP1, ERTS-ERIM-SP1

Question Answered: 9, 2, 11

Comments: Since the methods of extracting statistics differ considerably at LARS and ERIM, an estimation and comparison of variance components resulting from these two procedures will be made.

L.14 ANALYSIS X

Organization: LARS

Type of Data: ERTS

Factors: Correction and/or registration

Question Answered: 10

Comments: This analysis will determine the effect of ERTS data correction and registration on CCP. The effect will be assumed constant for all other ADP techniques.

L.15 ANALYSIS XI

Organization: LARS, EOD, ERIM

Type of Data: Aircraft - M²S, M-7, and C-130

Factors:

- Segments - three
- Times - one
- ADP techniques - M²S-LARS-SP1,
M²S-EOD-SP1, M²S-ERIM-PSP2

Question Answered: 12, 4, 1, 11

Comments: This analysis will compare the CCP's of three state-of-the-art scanners.